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WATER QUALITY MONITORING IN THE BIG THICKET NATIONAL PRESERVE, TURKEY CREEK UNIT

by

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ABSTRACT

Water quality of the streams of the Turkey Creek Unit of the Big Thicket National Preserve was studied from August, 1979 to July, 1980.

High chloride concentrations were detected during one of the twelve sampling periods. Bicarbonate alkalinity, pH, and carbon dioxide were low at all stations, a normal condition for tannic acid laden streams.

Bacterial contamination of streams in the Turkey Creek Unit was very slight.

A total of 6102 benthic macroinvertebrate organisms constituting 134 taxa were collected. The number of taxa for all collections ranged from 11 to 44, whereas the number of individuals for all collections varied from 41 to 766. Numbers of individuals per collection generally increased with discharge. Diversity ($\bar{d}$) values of all collections ranged from 1.31 to 4.38.

Excessive chlorides caused stress within the macrobenthic community during one of the four macroinvertebrate collection periods.

Faunal similarity between stations ranged from 0.55 to 0.70.

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INTRODUCTION

Public Law 92-439 established the Big Thicket National Preserve in October, 1974. Encompassing 34,217 hectares (84,550 acres), the preserve consists of eight land units and four river or stream corridors in southeast Texas. The Big Thicket region is unique in that several major ecosystems converge creating a biological crossroads found nowhere else in the United States.

It is expected that recreational use of the area, as well as development outside the preserve but in the watersheds will increase and this will have the potential of altering water quality of streams in the preserve. In order to evaluate water quality changes that may take place, it is necessary to obtain baseline data on present water quality.

In the final project reports of previous water quality surveys it was suggested that more data be obtained from all streams in the preserve (Harrel, 1976, 1977). It was also suggested that year-long studies be conducted on each stream in order to obtain extremes of physicochemical and biological conditions. Year-long studies have been completed in streams in the Beech Creek and Lance Rosier Units, the Little Pine Island-Pine Island Bayou Corridor and the Menard Creek Corridor.

Oil field activities currently occur in the Turkey Creek Unit and in the surrounding watershed. A canoe trail and hiking trails have already been established in the unit and general recreational

development has progressed faster in this unit than any other in the preserve.

The objectives of the present research were to: (1) determine baseline water quality data on the portions of Village Creek, Hickory Creek, and Turkey Creek that flow through the unit, (2) establish downstream and seasonal trends in water quality, (3) locate existing and potential sites of pollution, and (4) develop recommendations for management within the preserve.

A review of limnological and hydrological research in the Big Thicket National Preserve area was reported by Harrel and Watson (1975). Harrel et al. (1976) reported on water quality and benthic macroinvertebrates in the estuarine portion of the Neches River and Pine Island Bayou, some of which is in the preserve. Harrel (1976, 1977) in project reports to the National Park Service listed some baseline data on streams in the preserve, called attention to problem areas, and suggested priorities for additional monitoring. Kost (1977) studied the effect of lumbering activities on water quality and benthic macroinvertebrates in streams of the Beech Creek Unit. The Village Creek watershed, which contains four of the eight units of the preserve, was studied by Lewis and Harrel (1978) for macrobenthos and physicochemical conditions. Water quality, including bacteriological data and benthic macroinvertebrates, was studied by Darville (1978) in Little Pine Island Bayou and Pine Island Bayou in the preserve. Commander (1978) reported on the fecal coliform load and densities of coliform organisms in Pine Island Bayou during low flow (steady state) and storm runoff conditions. Bass (1979) studied physicochemical conditions, fecal coliform and macrobenthos in the Menard Creek Corridor.

Physicochemical and bacteriological data indicate water quality only at the time of sampling, while macrobenthos reflect present and past conditions. A healthy population of macroinvertebrate organisms consists of many different kinds of tolerant and intolerant organisms, but relatively few individuals within each taxa. Environmental stress reduces the diversity, complexity, and stability of the community by eliminating the intolerant organisms which are more sensitive to environmental changes (Patrick, 1970). The stress tolerant organisms then flourish in great numbers due to a decrease in competition for food and habitat and reduced chances for predation.

Community structure of benthic macroinvertebrates has frequently been used to evaluate water quality in aquatic ecosystems. Keup, et al. (1966) stated the following characteristics of macrobenthic organisms which make them useful for water quality studies: (1) long life cycles which may reflect conditions for an extended period of time, (2) low motility, (3) various ranges of tolerances to varying environmental conditions, and (4) they occupy central positions in aquatic food chains. Many others have used benthic macroinvertebrates as indicators of water quality (Gaufin and Tarzwell, 1952; Wilhm and Dorris, 1966; Harrel and Dorris, 1968; Harrel, 1969).

Many researchers have used mathematical indices to analyze community structure of benthic macroinvertebrates. The diversity index ($\bar{d}$) proposed by Shannon (1948) is possibly the most widely accepted of these. It was first used in ecological studies by Patten (1962) and later modified by Wilhm (1967) and Wilhm and Dorris (1968). This index reflects the evenness of taxa distribution, is dimensionless, and is relatively independent of sample size (Wilhm and Dorris, 1968). Wilhm

and Dorris (1968) concluded that $\bar{d}$ values of greater than 3 indicate clean water, values less than 1 indicate heavily polluted water, and intermediate values indicate moderate pollution. Many others have used $\bar{d}$ in investigations (Wilhm, 1967; Harrel and Dorris, 1968; Goodnight, 1973; Harrel and Duplechin, 1976; Kost, 1977; Darville, 1978; Lewis and Harrel, 1978; Bass, 1979).

Wilhm (1970) demonstrated the importance of obtaining asymptotic values ($\bar{d}$) of benthic macroinvertebrates in order to assure proper sample size.

The index of similarity (S) proposed by Sorenson (1948) may be applied to compare faunal similarity between stations. Coefficients of similarity calculated by this method will vary from zero for two stations with no taxa in common to one for two stations with identical faunal compositions and densities.

Winslow and Hunnewell (1902) were the first to use bacteria as indicators of fecal contamination. Geldreich and Kenner (1969) reported on the fecal coliform to fecal streptococci ratio and interpreted its meaning as follows:

FC : FS < 0.7	Animal fecal contamination only
FC : FS = 0.7 - 4.0	Mixture of animal and human fecal contamination
FC : FS > 4.0	Mostly human fecal contamination

Gallagher and Spino (1968) stated that whenever the FC:FS ratio is applied, all factors affecting the growth and survival of bacteria in a stream should be taken into account.

The Texas Department of Water Resources (1976) established

water quality criteria for each classified stream segment in the state of Texas. Village Creek, stream segment 0608, carries the following water quality restrictions:

Chloride:	avg. not to exceed 150 mg/l
Sulfate:	avg. not to exceed 75 mg/l
Total Dissolved Solids:	avg. not to exceed 300 mg/l
Dissolved Oxygen:	not less than 5.0 mg/l
Fecal Coliform:	log. avg. not more than 200 orgs/100 ml.
pH Range:	5.5 - 8.5
Temperature (Max.):	32 C (90 F)

These stream standards do not apply to the other streams within the Turkey Creek Unit.

The Lower Neches Valley Authority (1978), as participants in the 208 Areawide Wastewater Treatment Management Plan, published existing and projected land use and non-point source pollution loadings for the Village Creek watershed as well as many other watersheds within the Big Thicket National Preserve.

DESCRIPTION OF STUDY AREA

Few people can define the Big Thicket in finite terms. To most, it is a large wooded area in southeast Texas. To the experienced, however, the "thicket" is a mingling of wooded areas of great diversity. These areas combined form a region that once covered over 2.5 million acres. Today much of the "thicket" has been destroyed by human activity. The Big Thicket National Preserve was created to protect the best examples of what remain (National Parks Service, 1980). The Turkey Creek Unit is doubtlessly one of the most diverse and scenic units of the preserve.

The southern boundary of the unit extends along a portion of F. M. 420 located approximately 9.5 km (6 miles) north of Kountze (Figure 1). The southern portion of the unit encompasses a small portion of the Village Creek watershed including the lower 1.13 km (0.7 miles) of Hickory Creek. The remainder of the 3,157 hectare (7,800 acre) unit extends northward to F. M. 1943 with Turkey Creek flowing north to south through the approximate center of this portion of the unit.

The dominant overstory vegetation of the unit, described by Harcombe and Marks (1977), includes *Taxodium distichum* (bald cypress), *Liquidambar styraciflua* (sweetgum), *Fraxinus pennsylvanica* (green ash), *Pinus taeda* (loblolly pine), *Fagus grandifolia* (American beech), *Quercus nigra* (water oak), *Quercus falcata* (southern red oak), *Nyssa sylvatica* (black tupelo), *Quercus alba* (white oak), *Carya tomentosa* (mockernut hickory), and *Ulmus* spp. (elms). Other common species

Figure 1

Turkey Creek Unit of Big Thicket National Preserve
Location of Sampling Stations

include Carpinus caroliniana (American hornbeam), Acer rubrum (red maple), Ilex opaca (American holly), Ostrya virginiana (American hop-hornbeam), and Symplocus tinctoria (common sweetleaf).

The topographical basin occupied by the Big Thicket National Preserve is geologically young; its surface formations were deposited in the Pleistocene and Holocene epochs of the past few million years (United States Department of Interior, 1976). The Turkey Creek Unit is almost entirely situated on the Bentley formation. The Hockley Scarp, which separates the Willis and Bentley formations, runs roughly west to east on a line just north of the unit (Lower Neches Valley Authority, 1978).

The Turkey Creek Unit is situated within the Chicot ground-water aquifer, specifically within the Lissie Sands recharge zone (Lower Neches Valley Authority, 1978). This zone and the Willis Sands recharge zone, immediately to the north, represent relatively porous soil types which allow rapid percolation of rainwater into the ground, thus providing the all-important water recharge to a major portion of the Gulf Coast Aquifers. These sand outcroppings also provide vital base stream flow in the form of springs and seeps during periods of drought.

The general climate of the area is warm, temperate subtropical, characterized by humid, hot summers and mild, wet winters. The average rainfall is 135 cm (53 in.) per year. Mean temperatures range from 12 C (54 F) in January to 28 C (82 F) in August (United States Department of Interior, 1976).

The Turkey Creek Unit contains fourteen different soil types, the dominant type being Mantachie loam (United States Department of

Agriculture, 1978). The substrate at all sampling stations consisted of coarse sand with sparse pockets of silt and detritus.

There are five permitted waste discharges in the watersheds upstream from the Turkey Creek Unit (Table 1), all of which represent treated domestic wastewater. The total flow from all five point discharges is approximately 329,000 gallons per day with a total biochemical oxygen demand loading of approximately 30.4 lbs/day (Lower Neches Valley Authority, 1978). This BOD_5 loading is projected to increase to approximately 157 lbs/day, a five-fold increase, by the year 2000 (Lower Neches Valley Authority, 1978). The city of Woodville is presently contributing 99.9 percent of the total wasteload into the streams of the unit. By the year 2000 their projected wasteload volume will triple but due to the projected increase in loading from other dischargers, the contribution from the city of Woodville will decrease to 63 percent of the total load (Lower Neches Valley Authority, 1978).

For the present study seven sampling stations were established, three on Village Creek, three on Turkey Creek and one on Hickory Creek (Figure 1).

Station VC-1. Located on Village Creek approximately 50 meters upstream from the confluence with Hickory Creek.

Station VC-2. Located on Village Creek approximately half the distance between the confluences of Hickory and Turkey Creeks with Village Creek.

Station VC-3. Located on Village Creek approximately 30

Table 1

Permitted Waste Discharges Upstream From the Turkey Creek Unit (LNVA, 1978)

Permit No.	Name of Discharger	Volume (gpd)	Type	Wasteload, BOD_5 (lbs./day)	Receiving Stream
10322-01	City of Woodville	310,000	Domestic	30	Turkey Creek
10322-02	City of Woodville	Proposed	Domestic	Proposed	Turkey Creek
11562-01	Alabama-Coushatta Indian Reservation	10,000	Domestic	0.082	Big Sandy Creek
11184-01	Wildwood Resort City	0	Domestic	Total Retention	Village Creek
11307-01	Warren Independent School District, Warren High School	4,000	Domestic	0.13	Hickory Creek
11308-01	Warren Independent School District, Warren Junior High School	5,000	Domestic	0.18	Hickory Creek

meters downstream from the confluence of Turkey Creek with Village Creek.

Station HC-1. Located on Hickory Creek approximately 50 meters upstream from the confluence with Village Creek.

Station TC-1. Located on Turkey Creek, approximately 35 meters downstream from F. M. 1943, east of Warren near the north boundary.

Station TC-2. Located on Turkey Creek, at bridge crossing of county road (locally known as Hicksbaugh Road) west of Pleasant Valley Church.

Station TC-3. Located on Turkey Creek approximately 40 meters upstream from the confluence with Village Creek.

During the study, depth at the three Village Creek stations ranged from 1.2 m (4 ft.) to 4.3 m (9 ft.). Depth at Station HC-1 ranged from 0.4 m (1.3 ft.) to 1.4 m (4.6 ft.). Depth at the three Turkey Creek stations ranged from 0.3 m (0.9 ft.) to 1.5 m (4.8 ft.).

METHODS

Samples for physicochemical data and bacteria were obtained monthly from August, 1979 to July, 1980 (Table 2). Standard BOD bottles were submerged to obtain water for physicochemical data and sterlized 100 ml screw-cap flint glass bottles were used to collect samples for bacteriological analysis.

Physicochemical conditions were measured using either Standard Methods procedures (American Public Health Association, 1975) or Hach Chemical Company procedures (Hach Chemical Company, 1975). Appendix A lists each method used to obtain physicochemical data.

Numbers of fecal coliforms and fecal streptococci were determined by the membrane filter technique (American Public Health Association, 1975) utilizing Millipore, Corp., technology. The fecal coliform to fecal streptococci ratio (FC/FS) was determined after the method of Geldreich and Kenner (1969).

Benthic macroinvertebrates were collected seasonally, using a petite Ponar dredge (15.24 cm by 15.24 cm), at Stations VC-2, HC-1, TC-1, TC-2, and TC-3. Macrobenthos were not collected from Stations VC-1 and VC-3 due to their close proximity to Stations VC-2, HC-1, and TC-1. Six samples were collected at each station and washed through a No. 30 mesh sieve bucket. Each subsample was preserved separately in glass jars and stained with rose bengal dye to facilitate sorting the organisms in the laboratory (Mason and Yevich, 1967). In the laboratory the samples were rinsed into a No. 30 mesh soil sieve and all organisms were sorted, identified and enumerated.

Table 2

Collection Dates - Turkey Creek Unit

Date	Physicochemical and Bacteria	Benthic Macroinvertebrates
August 21, 1979	*	
September 17, 1979	*	
October 19, 1979	*	*
November 30, 1979	*	
December 20, 1979	*	
January 29, 1980	*	
February 26, 1980	*	*
March 25, 1980	*	
April 22, 1980	*	*
May 27, 1980	*	
June 18, 1980	*	
July 15, 1980	*	*

Shannon's diversity index (1948) as proposed by Margalef (1958) and modified by Patten (1962) and Wilhm and Dorris (1968) was calculated for each station for each collection and for each station annually using the formula:

$$\bar{d} = - \Sigma (n_i/n) \log_2 (n_i/n)$$

where $\bar{d}$ = diversity per individual

n = total number of individuals

n_i = number of individuals of species i

These calculations were computed using a Texas Instruments Model 59 programmable calculator.

Sorenson's (1948) index of similarity was modified to compare the overlap of taxa occurring between all pairs of stations by the formula:

$$S = \frac{2\ C}{A + B}$$

where A = number of taxa at station A

B = number of taxa at station B

C = number of taxa common to both stations

There are no United States Geological Survey stream gaging stations within the Turkey Creek Unit. Discharge measurement stations were established at the following locations:

Village Creek at McNeely Bridge, representing total flow of all streams exiting the unit

Village Creek at U. S. 69, 287, representing a major tributary flowing into the unit

Hickory Creek at County Line Road, representing a major tributary flowing into the unit

Turkey Creek at County Line Road, representing the discharge in this stream in the central portion of the unit

Turkey Creek at F. M. 1943 (Study Sta. TC-1), representing the flow of Turkey Creek as it enters the unit.

During each sampling period the height of the stream surface was measured using a prescribed mark on the bridge under which the stream was flowing. By using the same reference mark each time, an accurate comparison was obtained of the differential head at each discharge measurement station for each sampling period. Then as time permitted, an actual discharge measurement was performed at each of these stations using a Marsh-McBirney Model 201 portable water current meter. Discharge measurements were made at low (steady state) flow, moderate flow, and high flow conditions. These data were used to establish a discharge curve plotting the temporary gage height reading at the time of actual discharge measurements against the actual measured discharge. The discharge during all sampling periods was estimated by using these rating curves with interpolation based on the location of the sampling station in relation to the discharge measurement stations.

PHYSICOCHEMICAL CONDITIONS

Temperature

Water temperatures varied from 8.5 C in November at Station VC-2 to 28.5 C in July at Stations TC-1 and TC-2 (Table 3, Appendix B). Temperatures generally followed seasonal trends and no violations of established stream standards were observed (Texas Department of Water Resources, 1976).

Dissolved Oxygen and D. O. Saturation

Dissolved oxygen varied from 6.2 mg/l in July at Station VC-1 to 11.2 mg/l in November at Station TC-2 (Table 3, Appendix B). Dissolved oxygen values fluctuated with temperature following Henry's and Dalton's Laws, and no violations of established stream standards were observed (Texas Department of Water Resources, 1976).

Dissolved oxygen saturation values, calculated from tables of oxygen saturation values by Truesdale et al. (1955), varied from 79 percent in May at Station VC-1 to 103 percent in December at Station TC-1, values indicative of clean water (Table 3, Appendix B).

Biochemical Oxygen Demand

BOD_5 values ranged from 0.2 mg/l in June at Station TC-3 to 3.2 mg/l in November at Station HC-1 (Table 3, Appendix B). These values are within the range commonly recognized as "clean water" (Hynes, 1974).

Carbon Dioxide, Total Alkalinity, and pH

Carbon dioxide values varied from 2 mg/l in December at Station

Table 3

Extremes of Physicochemical Conditions of Streams of the Turkey Creek Unit
August, 1979 thru July, 1980

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., C	9 - 28	8.5 - 28	9.5 - 28	9 - 27.5	9 - 28.5	9 - 28.5	9.5 - 27.8
Dissolved Oxygen, mg/l	6.2 - 10.4	6.6 - 10.9	6.7 - 10.6	7.1 - 11	7.4 - 11	7 - 11.2	6.8 - 11
O_2 Saturation, %	79 - 95	80 - 100	83 - 97	86 - 99.3	92 - 103	87 - 102	83 - 99.3
BOD_5, mg/l	0.8 - 2.3	0.4 - 2.1	0.4 - 2.3	0.5 - 3.2	0.6 - 2.4	0.4 - 3.1	0.2 - 2.6
CO_2, mg/l	4 - 12	3 - 9.5	4.5 - 9	4 - 12	2 - 9.5	3 - 8	2.5 - 9
Total Alkalinity, mg/l	9 - 20	9 - 18	9 - 24	9 - 14	10 - 20	10 - 24	9 - 20
pH	5.1 - 6.6	5.1 - 6.6	5.3 - 6.4	5.1 - 6.3	5.3 - 6.5	5.3 - 6.5	5.2 - 6.4
Spec. Cond., umhos/cm	54 - 410	51 - 290	51 - 206	44 - 83	42 - 63	41 - 62	42 - 62
Chloride, mg/l	12.5 - 136	12 - 88	12 - 60	11.5 - 20	9.5 - 17	9.5 - 12.5	10 - 12.5
Turbidity, JTU	51 - 109	51 - 109	51 - 109	51 - 114	47 - 106	56 - 109	47 - 97
Apparent Color, APHA units	115 - 270	110 - 275	100 - 270	80 - 285	80 - 250	80 - 250	90 - 218
PO_4, mg/l	0.01 - 0.12	0.01 - 0.09	0.01 - 0.11	0.01 - 0.16	0.05 - 0.22	0.07 - 0.22	0.06 - 0.16
NH_4, mg/l	0.58 - 1.79	0.5 - 1.74	0.54 - 1.84	0.52 - 1.84	0.44 - 1.29	0.46 - 1.25	0.44 - 1.22
NO_3, mg/l	0.001 - 0.008	0.001 - 0.011	0.001 - 0.014	0.002 - 0.012	0.003 - 0.023	0.003 - 0.022	0.003 - 0.021
Total Iron, mg/l	.92 - 1.77	.89 - 1.51	.84 - 1.51	.84 - 1.61	.89 - 1.72	.92 - 1.77	.99 - 1.56
TSS, mg/l	6 - 62	5 - 47	8 - 62	5 - 55	8 - 68	7 - 45	8 - 43
TDS, mg/l	6 - 226	9 - 170	46 - 152	46 - 102	15 - 150	14 - 154	40 - 82
TDO, mg/l	4 - 110	7 - 74	2 - 130	14 - 48	11 - 98	0 - 110	4 - 58
TDI, mg/l	2 - 200	2 - 132	6 - 102	12 - 56	4 - 54	1 - 82	6 - 68
Chlorophyll "a", mg/l	0.0 - 0.034	0.0 - 0.027	0.0 - 0.027	0.0 - 0.027	0.0 - 0.02	0.0 - 0.013	0.0 - 0.027

TC-1 to 12 mg/l in October at Stations VC-1 and HC-2 (Table 3, Appendix B). These values generally followed the fluctuations of pH values.

Only bicarbonate alkalinity was present and it ranged from 9 mg/l in November at Stations VC-1, VC-2, VC-3, HC-1, and TC-3 to 24 mg/l in July at Stations VC-3 and TC-2 (Table 3, Appendix B). Alkalinity values also fluctuated with pH.

The pH values ranged from 5.1 at Stations VC-1, VC-2 and HC-1 during January to 6.6 at Stations VC-1 and VC-2 during July. The low pH readings in January were obtained during a period of high rainfall when runoff volumes were high, whereas the high pH readings in July were obtained during a severe drought when only base flow existed in all the streams. It is interesting to note that each sampling station was in violation of the pH standard (range: 5.5 - 8.5) established by the Texas Department of Water Resources (1976) during the January sampling period. These low pH values are perfectly normal for Big Thicket streams, especially during periods of excessive runoff, due to tannic acid leachates from leaves and other natural organic matter on the forest floor.

Specific Conductance and Chlorides

Specific conductance ranged from 41 umhos/cm in December at Station TC-2 to 410 umhos/cm at Station VC-1 (Table 3, Appendix B). The high specific conductance reading was obtained on April 22, 1980. All three Village Creek sampling stations had high specific conductance values during that sampling period. Comparing these values to all other values (annual) for those stations it is concluded that oil field brine was the cause of these anomalous specific conductance values.

Chloride values ranged from 9.5 mg/l in May at Stations TC-1 and TC-2 to 136 mg/l at Station VC-1 (Table 3, Appendix B). The high chloride value occurred during the April 22, 1980 sampling period and fluctuated directly with specific conductance values. Although the established water quality criteria was not exceeded by these parameters, the potential for such to occur seems very real unless the release of oil field brine is more closely regulated.

Turbidity and Apparent Color

Turbidity values ranged from 47 Jackson Turbidity Units at Stations TC-1 and TC-3 in July to 114 Jackson Turbidity Units at Stations HC-1 in March (Table 3, Appendix B). Turbidity values obviously fluctuated with stream discharge and volumes of runoff since the high reading was obtained during a near-flooded condition and the low values were obtained during a severe drought.

Apparent color ranged from 80 APHA units at Stations HC-1, TC-1, and TC-2 during July to 285 APHA units at Station HC-1 during March (Table 3, Appendix B). Since apparent color is very closely related to turbidity (in fact, the determinations interfere with each other), these values fluctuated directly with turbidity.

Orthophosphates

Orthophosphate concentrations ranged from 0.01 mg/l in February at Stations VC-1, VC-2, VC-3 and HC-1 to 0.22 mg/l in July at Stations TC-1 and TC-2 (Table 3, Appendix B). All values were within the range considered to be "normal" for natural lotic waters (Connell, 1972).

Total Iron

Total iron values ranged from 0.84 mg/l in November at Stations VC-3 and HC-1 to 1.77 mg/l at Stations VC-1 and TC-2 during August and March, respectively (Table 3, Appendix B). The soil within the watershed of the three streams sampled is heavily laden with iron oxides. Total iron values in streams of the Big Thicket are usually elevated.

Ammonia Nitrogen

Ammonia nitrogen values ranged from 0.44 mg/l at Stations TC-1 and TC-3 during October and June, respectively, to 1.84 mg/l at Stations VC-3 and HC-1 during March (Table 3, Appendix B). Elevated iron values interfere with the Nesslerization method for determination of ammonia nitrogen by causing falsely high readings (Hach Chemical Company, 1975). The ammonia nitrogen values thus reported in this study are inaccurate and should not be considered.

Nitrate Nitrogen

Nitrate nitrogen values ranged from 0.001 mg/l in March at the Village Creek stations to 0.023 mg/l in July at Station TC-1 (Table 3, Appendix B).

Total Suspended Solids

Total suspended solids ranged from 5 mg/l at Stations VC-2 and HC-1 during July and August, respectively, to 68 mg/l at Station TC-1 during March (Table 3, Appendix B). Total suspended solids in natural lotic waters of southeast Texas fluctuate directly with turbidity and relative volume of runoff.

Total Dissolved Solids

Total dissolved solids fluctuated from 6 mg/l in September at

Station VC-1 to 226 mg/l at Station VC-1 during April (Table 3, Appendix B). Total dissolved solids usually fluctuate directly with specific conductance. The high TDS value obtained at Station VC-1 was during the April 22, 1980 sampling period when the alleged oil field brines were detected at all three Village Creek stations. A closer examination of the data reveals that the total dissolved inorganic solids for Station VC-1 during the April sampling period was 200 mg/l, a value excessively high compared to the TDI values for this station during the other eleven sampling periods. The total dissolved organic solids value for Station VC-1 during the sampling period was 26 mg/l, a value compatible with the remaining TDO data for that station.

Chlorophyll "a"

Chlorophyll "a" concentrations, as determined after the procedure of Richards and Thompson (1952) and later modified by Odum et al. (1958), ranged from zero for all stations during several collections to 0.034 mg/l at Station VC-1 during the July sampling period (Table 3, Appendix B). All the levels detected were below the value (0.05 mg/l) considered indicative of nuisance aquatic plant growths (Texas Water Quality Board, 1974).

HYDROLOGY

Hydrologic data is nonexistent within the Turkey Creek Unit. The nearest United States Geological Survey stream gaging station is located on Village Creek at F. M. 418 approximately 20 kilometers (12.4 miles) downstream from the southeast corner of the unit. The data from that gaging station (Sta. No. 08041500) is excellent and is summarized in Table 4 (U.S.G.S., 1980).

The discharge listed in the table for each collection period demonstrates the general hydrologic conditions of the Village Creek watershed at the time of sampling, however, these data cannot be used to indicate hydrologic conditions in the two smaller tributaries, Hickory Creek and Turkey Creek, which flow through the unit. For this reason, a method was devised to obtain discharge estimates at each sampling station for all sampling periods by constructing discharge rating curves. These data are summarized in Table 5.

It is interesting to note that the discharge estimate of Turkey Creek during the July sampling period, a period of severe drought, was almost equal to the sum of the discharges of Village and Hickory Creeks. The conditions during the July sampling period represented absolute base flow. In fact, the discharge from Turkey Creek exceeded the discharge of Village Creek at Station VC-1, a total of five sampling periods out of twelve (Table 5). These data seem to indicate that Turkey Creek is a more "permanent" stream than Hickory Creek or the portion of Village Creek upstream from the Turkey Creek Unit.

Table 4

Stream Discharge (M^3/sec.) of Village Creek at F.M. 418
During Collection Periods and Monthly Means

Collection Date	Discharge	Mean Monthly Discharge
August 21, 1979	8.5	16.3
September 17, 1979	4.6	50.8
October 19, 1979	6.9	10.9
November 30, 1979	53.0*	40.9**
December 20, 1979	33.1	31.4
January 29, 1980	47.6	49.0
February 26, 1980	23.5	53.6
March 25, 1980	36.0	45.1
April 22, 1980	18.5	59.5
May 27, 1980	26.4	56.6**
June 18, 1980	5.9	8.1
July 15, 1980	2.8	3.2**

*Data represents discharge on November 29, 1980

**Mean computed from incomplete monthly data

Table 5

Stream Discharge at Each Sampling Station
During all Sampling Periods

	Discharge (M^3/sec.)						
Collection Date	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
August 21, 1979	3.3	5.4	8.1	2.1	2.7	2.7	2.7
September 17, 1979	2.2	3.2	4.4	1.0	1.2	1.2	1.2
October 19, 1979	2.5	4.0	6.6	1.5	2.6	2.6	2.6
November 30, 1979	12.2	19.3	28.7	7.1	5.4	7.4	9.4
December 20, 1979	9.0	16.9	27.3	7.9	6.2	8.3	10.4
January 29, 1980	12.8	20.8	32.5	8.0	6.3	9.0	11.7
February 26, 1980	8.0	14.6	22.3	6.6	4.3	6.0	7.7
March 25, 1980	13.6	21.3	33.3	7.7	8.0	8.8	12.0
April 22, 1980	7.1	12.3	17.6	5.2	4.3	4.5	5.3
May 27, 1980	8.7	15.9	25.3	7.2	6.0	7.7	9.4
June 18, 1980	1.8	3.3	5.6	1.5	2.3	2.3	2.3
July 15, 1980	0.7	1.2	2.3	0.5	1.1	1.1	1.1

BIOLOGICAL CONDITIONS

Bacteria

Numbers of fecal coliform organisms ranged from 4 organisms/100 ml. at Station VC-1 during June to 288 organisms/100 ml. at Station TC-1 during March, a period of excessive runoff (Table 6). Numbers of fecal streptococci ranged from 10 organisms/100 ml. during February at Station VC-1 to 720 organisms/100 ml. at Station TC-1 during August (Table 6).

The fecal coliform to fecal streptococci ratio (FC/FS) ranged from 0.03 at Station VC-1 during June and July to 7.6, also at Station VC-1, during February (Table 6). Only one of the 84 individual samples had a ratio above 4.0 indicating primarily human contamination. Fifty-nine of the 84 individual samples had ratios below 0.7 indicating contamination by warm blooded animals other than human.

Bacterial contamination of streams in the Turkey Creek Unit was very slight. No trends in bacteriological data were evident other than increases during periods of excessive runoff. Based on stream criteria for fecal coliform established for Village Creek by the Texas Department of Water Resources (1976), the streams of the Turkey Creek Unit should be safe for contact recreation.

Benthic Macroinvertebrates

A total of 6102 benthic macroinvertebrates constituting 134 taxa were collected (Table 7, Appendix C). Oligochaeta (64.2%), Amphipoda (4.0%), Ephemeroptera (2.0%), Chironomidae (18.3%), Ceratopogonidae (4.4%), Trichoptera (1.9%), Gastropoda (0.9%), and Pelecypoda

Table 6

Numbers of Fecal Coliform (FC)
and Fecal Streptococci (FS)/100 ml
and FC/FS Ratios

Date		Station						
		VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
August 21, 1979	FC	24	40	60	40	196	168	72
	FS	240	175	295	270	720	430	540
	FC/FS	0.1	0.23	0.2	0.15	0.27	0.39	0.13
September 17, 1979	FC	12	24	28	48	60	28	64
	FS	140	160	280	170	670	160	210
	FC/FS	0.09	0.15	0.1	0.28	0.09	0.18	0.30
October 19, 1979	FC	28	60	120	40	48	104	64
	FS	210	210	240	200	280	160	250
	FC/FS	0.13	0.29	0.5	0.2	0.17	0.65	0.26
November 30, 1979	FC	96	116	96	96	80	132	148
	FS	160	220	420	200	260	260	160
	FC/FS	0.6	0.53	0.23	0.48	0.31	0.51	0.93
December 20, 1979	FC	32	56	72	80	148	120	92
	FS	100	100	100	90	80	110	90
	FC/FS	0.32	0.56	0.72	0.89	1.85	1.2	1.02
January 29, 1980	FC	108	108	92	68	120	116	108
	FS	80	130	40	40	140	70	100
	FC/FS	1.35	0.83	2.3	1.7	0.86	1.66	1.08
February 26, 1980	FC	76	44	36	112	40	48	64
	FS	10	60	40	50	70	50	80
	FC/FS	7.6	0.73	0.9	2.24	0.57	0.96	0.8
March 25, 1980	FC	76	92	136	80	288	248	92
	FS	250	160	210	140	240	340	100
	FC/FS	0.3	0.58	0.65	0.57	1.2	0.73	0.92
April 22, 1980	FC	40	72	56	48	148	120	80
	FS	150	100	48	70	150	260	150
	FC/FS	0.27	0.72	1.17	0.69	0.99	0.46	0.53
May 27, 1980	FC	52	44	36	72	60	44	20
	FS	540	350	370	580	360	380	360
	FC/FS	0.1	0.13	0.1	0.12	0.17	0.12	0.06

Table 6 (continued)

Date		Station						
		VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
June 18, 1980	FC	4	12	32	32	32	32	20
	FS	160	270	200	340	260	190	180
	FC/FS	0.03	0.04	0.16	0.09	0.12	0.17	0.11
July 15, 1980	FC	8	40	32	52	24	92	20
	FS	260	320	340	330	110	220	270
	FC/FS	0.03	0.13	0.09	0.16	0.22	0.42	0.07

Table 7

Numbers of Benthic Macroinvertebrates Collected From
Turkey Creek Unit Streams
(Annual List)

Organism	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Platyhelminthes					
Turbellaria					
Tricladida					
Dugesia sp.	2		4		
Nematoda	4	1	5	8	14
Nematomorpha			1		
Annelida					
Oligochaeta					
Naididae					
Nais sp.					1
Opistocystidae					
Opistocysta tribranchiata		1			
Tubificidae					
Branchiura sowerbyi			118	27	1
Limnodrilus hoffmeisteri	796	765	349	642	618
Aulodrilus pigueti	4		2		10
Peloscolex sp.	133	32	86	54	47
Tubifex sp.	8	2	3	6	56
Enchytraeidae					
Enchytraeus sp.	7	3	2	21	3
Lumbriculidae					
Lumbriculus variegatus	19	2	33	7	46
Rhynchelmis sp.					2
Hirudinea					
Glossiphoniidae					
Glossiphonia complanata			1		
Helobdella fusca			1		
Rhynchobdellidae					
Actinobdella annectens			2		1
Erpobdellidae					
Erpobdella sp.	2		2		4
Arthropoda					
Crustacea					
Isopoda					
Asellus intermedius					1
Asellus militaris				1	1
Asellus sp.	2				
Amphipoda					
Gammarus sp.	8		168	31	11

Table 7 (continued)

Organism	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Hyalella azteca	2	1		1	
Crangonyx sp.	1	3	10	1	
Synurella sp.	2	1	2		
Decapoda					
Cambarellus puer			1		1
Orconectes sp.		1			
Palaemonetes kadiakensis				2	
Immature Decapoda	2				
Insecta					
Odonata					
Hagenius brevistylus	1			1	
Gomphus pallidus		2			
Gomphus sp.	1		2	7	4
Gomphoides sp.		2			
Dromogomphus spinosus			1		
Dromogomphus spoliatus					1
Dromogomphus sp.	2		1	3	3
Erpetogomphus sp.				2	
Unknown Gomphidae		1			
Cordulegaster sp.		1			
Neoneura sp.				1	
Plecoptera					
Perlesta sp.		1			
Ephemeroptera					
Stenonema femoratum	1				
Stenonema smithae	3				
Stenonema sp.	31	5	6	6	4
Hexagenia rigida		13	3		
Hexagenia limbata	15	6	5		7
Hexagenia recurvata				1	
Caenis sp.	7		2	1	
Callibaetis sp.				2	1
Neocloeon sp.				1	
Pseudocloeon sp.				1	
Siphlonurus sp.				1	
Coleoptera					
Ancyronyx variegata				1	
Stenelmis sp.	6	2	1	8	19
Dubiraphia sp.		1			
Diptera					
Tipulidae					
Hexatoma sp.		1	1	3	1
Simuliidae					

Table 7 (continued)

Organism	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Simulium sp.				2	
Tanypodinae					
Ablabesmyia hauberi	5		11	1	
Ablabesmyia mallochi			1	5	2
Ablabesmyia ornata	3	1			2
Ablabesmyia aspera	2	2		3	
Ablabesmyia annulata		4	1		1
Ablabesmyia cinctipes				1	
Ablabesmyia tarella			1		3
Ablabesmyia sp.	4				
Nilotanypus sp.	1				
Larsia sp.			1		
Thienemannimyia - group	2		2		
Tanypus sp.	1				
Procladius sp.		4			
Clinotanypus sp.			1		1
Chironominae					
Polypedilum halterale	38	13	10	40	41
Polypedilum illinoense	2	3	7	7	30
Polypedilum convictum	3	2	1	17	16
Polypedilum ophioides	34	11	6	7	15
Polypedilum fallax	1				1
Tribelos fuscicornis	23	12	7	31	33
Tribelos jucundus	26	10	4	16	40
Tribelos sp.	6			1	1
Tanytarsus sp.	18	21	19	15	21
Stenochironomus sp.	5		2	16	2
Chironomus attenuatus	1				
Chironomus sp.	3		1		
Cryptochironomus digitatus	17	11	7	9	21
Cryptochironomus fulvus	4	1	1	2	4
Cryptochironomus blarina	5		2	1	2
Nilothauma sp.	1				1
nr *Nilothauma* sp.	15	2	1	11	5
Zavrelia sp.		1			
Micropsectra sp.	1	2	8	18	8
Demicryptochironomus sp.		1	3		2
Paratanytarsus sp.			2		
Cladotanytarsus sp.		14	2	1	
Stempellina sp.			1		
Rheotanytarsus sp.		2	3	10	1
Glyptotendipes sp.				2	
Microtendipes sp.					1

Table 7 (continued)

Organism	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Nimbocera sp.					1
Stictochironomus sp.	18	17	8	20	19
Paralauterborniella nigrohalteralis		4	1	13	6
Paralauterborniella elachista		1			
Leptochironomus sp.					1
Podionomus beckae					1
Robakia sp.	16	18		2	3
Dicrotendipes modestus	2				
Paratendipes connectens				1	
Unknown Tanytarsini	4				
Unknown Chironomini					1
Orthocladiinae					
Eukiefferiella sp.	18		5	9	
Smittia sp.				2	
Corynoneura sp.	2				
Rheocricotopus sp.	1				
Brillia sp.	1				
Psectrocladius vernalis		1			1
Psectrocladius sp.	1		1	1	
Unknown Orthocladiinae				4	
Ceratopogonidae					
Palpomyia tibialis	20	29	28	35	104
Palpomyia sp.	11	3	11	14	2
Culicoides sp.		1	1	1	
Stilobezzia sp.		2	5	1	
Trichoptera					
Hydropsychidae					
Macronemum sp.				13	
Psychomyiidae					
Polycentropus centralis	3				
Polycentropus sp.				2	
Phylocentropus sp.	17	11	8	26	15
Philoptamidae					
Chimarra sp.	2	4		1	
Hydroptilidae					
Agraylea sp.		1			
Leptoceridae					
Oecetis sp.	1	5	1	3	4
Leptocerus sp.				1	
Megaloptera					
Sialidae					
Sialis sp.				1	

Table 7 (continued)

Organism	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Mollusca					
Gastropoda					
Amnicola sp.	8	4	9	16	7
Campeloma sp.			5	5	
Pelecypoda					
Sphaerium sp.	30	22	13	42	12
Glebula rotundata				1	
Lampsilis sp.			5	1	
Unknown Pelecypoda			2		1
Total Number Individuals	1435	1087	1020	1271	1289
Total Number Taxa	66	56	68	73	63
Annual Diversity ($\bar{d}$)	3.15	2.34	3.67	3.58	3.45

(2.1%) constituted 97.8% of the total fauna (Table 8).

No trends were evident in the number of taxa collected at each station during each collection period. The least number of taxa (11) was collected at Station TC-1 during April, whereas the greatest number of taxa (44) was collected at Station TC-2 during October (Table 9). The numbers of individuals collected at Stations VC-2, HC-1, and TC-3 varied with extremes of discharge. Numbers of individuals generally increased at these stations as discharge increased. The numbers of individuals collected at Stations TC-1 and TC-2 varied erratically with station and month. The greatest number of individuals (766) was collected at Station HC-1 during February, only a few days following a period of severe over-bank flooding. The least number of individuals (41) was collected at Station HC-1 during July during a period of severe drought when all the streams contained only base flow which had stabilized the discharge patterns for a period of approximately twenty days prior to sampling.

Oligochaetes dominated the fauna at all stations, ranging from 74.1% at Station HC-1 to 58.7% at Station TC-1 (Table 8). The diversity of oligochaetes, however, was surprisingly low compared to previous studies of Big Thicket streams (Lewis, 1974; Kost, 1977; Darville, 1978; Bass, 1979). Only one Naididae specimen was collected among all the stations for all collections. The eurytolerant oligochaete, Limnodrilus hoffmeisteri was the dominant organism at each station. Its annual occurrence ranged from 34% at Station TC-1 to 70% at Station HC-1.

The percent composition of Limnodrilus hoffmeisteri varied directly with discharge at each station (Table 10). The most dramatic

Table 8

Annual Numbers and Percent Composition of Major Taxonomic Groups at Each Station and all Stations Combined

Group		Station					
		VC-2	HC-1	TC-1	TC-2	TC-3	Annual
Oligochaeta	Number	969	805	599	757	789	3919
	Percent	67.5	74.1	58.7	59.6	61.2	64.2
Amphipoda	Number	13	5	180	33	11	242
	Percent	0.9	0.5	17.6	2.6	0.9	4.0
Ephemeroptera	Number	57	24	16	13	12	122
	Percent	4.0	2.2	1.6	1.0	0.9	2.0
Chironomidae	Number	284	158	120	266	287	1115
	Percent	19.8	14.5	11.8	20.9	22.3	18.3
Ceratopogonidae	Number	31	35	45	51	106	268
	Percent	2.2	3.2	4.4	4.0	8.2	4.4
Trichoptera	Number	23	21	9	46	19	118
	Percent	1.6	1.9	0.9	3.6	1.5	1.9
Gastropoda	Number	8	4	14	21	7	54
	Percent	0.6	0.4	1.4	1.7	0.5	0.9
Pelecypoda	Number	30	22	20	44	13	129
	Percent	2.1	2.0	2.0	3.5	1.0	2.1
Total Number		1415	1074	1003	1231	1244	5967
Total Percent		98.7	98.8	98.4	96.9	96.5	97.8

Table 9

Variations in Numbers of Individuals, Taxa, and Diversity ($\bar{d}$)

Collection Date		Station				
		VC-2	HC-1	TC-1	TC-2	TC-3
October 19, 1979	Indiv.	92	73	431	405	224
	Taxa	30	18	36	44	24
	$\bar{d}$	4.38	3.54*	3.29*	3.34	2.98
February 26, 1980	Indiv.	644	766	180	438	518
	Taxa	40	26	28	39	42
	$\bar{d}$	2.47	1.31	2.65*	2.68	3.08*
April 22, 1980	Indiv.	525	211	97	220	472
	Taxa	24	29	11	30	29
	$\bar{d}$	1.96*	3.25*	1.84	3.23*	2.98
July 15, 1980	Indiv.	178	41	311	213	82
	Taxa	24	13	34	21	24
	$\bar{d}$	3.76*	3.26	2.87*	3.05*	3.54
Annual	Indiv.	1435	1087	1020	1271	1289
	Taxa	66	56	68	73	63
	$\bar{d}$	3.15	2.34	3.67	3.58	3.45

*Represents at least 95% of asymptotic diversity value

Table 10

Percent Composition of *Limnodrilus hoffmeisteri* for all Collections Correlated to Discharge

Collection Date		Station				
		VC-2	HC-1	TC-1	TC-2	TC-3
October 19, 1979	% Composition	16.3	16.4	32.3	46.7	45.1
	Discharge (M^3/sec.)	4.0	1.5	2.6	2.6	2.6
February 26,1980	% Composition	60.9	85.0	60.6	62.3	53.5
	Discharge (M^3/sec.)	14.6	6.6	4.3	6.0	7.7
April 22, 1980	% Composition	68.8	46.0	64.9	43.6	45.1
	Discharge (M^3/sec.)	12.3	5.2	4.3	4.5	5.3
July 15, 1980	% Composition	15.7	12.2	12.2	39.4	32.9
	Discharge (M^3/sec.)	1.2	0.5	1.1	1.1	1.1

variation was exhibited at Station HC-1 where the extremes ranged from 12.2% in July when discharge was very low (0.5 M^3/sec.) to 85.0% in February when discharge was relatively high (6.6 M^3/sec.). The organism, being tolerant to most physical and chemical perturbations, flourished in the absence of competition after other bentnic organisms were apparently washed downstream by the scouring effects of high discharge. Macrobenthos at other stations exhibited similar effects from scouring.

Chironomidae constituted the second most dominant taxonomic group with extremes ranging from 22.3% at Station TC-3 to 11.8% at Station TC-1 (Table 8). The diversity of chironomids was significant when compared to previous studies of Big Thicket streams (Lewis, 1974; Kost, 1977; Darville, 1978; Bass, 1979). Fifty-nine taxa of chironomids are reported in the present study as compared to a maximum of fifty-two reported in previous studies (Kost, 1977).

The midge Polypedilum halterale was the dominant chironomid at Stations VC-2, TC-2, and TC-3, constituting 2.6%, 3.1% and 3.2% respectively, of all individuals (Table 11). The midge Tanytarsus sp. was the dominant chironomid at Stations HC-1 and TC-1, constituting 1.9% of all individuals.

The ceratopogonid Polpomyia tibialis was collected at all stations. It ranged in abundance from 1.4% at Station VC-2 to 8.1% at Station TC-3 (Table 11).

The trichopteran Phylocentropus sp. was collected at all stations. Its abundance was relatively uniform, ranging from 1.0% at Station HC-1 to 2.0% at Station TC-2 (Table 11). The only other caddisfly collected at all stations was Oecetis sp. and its abundance

Table 11

Annual Percent Composition of Macrobenthos for Each Station and all Stations Combined, Excluding Taxa Which Constituted Less Than one Percent at any Station

	Station					
Organism	VC-2	HC-1	TC-1	TC-2	TC-3	Annual
Nematoda					1.1	0.5
Branchiura sowerbyi			11.6	2.1		2.4
Limnodrilus hoffmeisteri	55.5	70.4	34.2	50.5	47.9	52.0
Peloscolex sp.	9.3	2.9	8.4	4.2	3.6	5.8
Tubifex sp.					4.3	1.2
Enchytraeus sp.				1.7		0.6
Lumbriculus variegatus	1.3		3.2		3.6	1.8
Gammarus sp.			16.5	2.4		3.6
Crangonyx sp.			1.0			0.2
Stenonema sp.	2.2					0.9
Hexagenia rigida		1.2				0.3
Hexagenia limbata	1.0					0.5
Stenelmis sp.					1.5	0.6
Ablabesmyia hauberi			1.1			0.3
Polypedilum halterale	2.6	1.2	1.0	3.1	3.2	2.3
Polypedilum illinoense					2.3	0.8
Polypedilum convictum				1.3	1.2	0.6
Polypedilum ophioides	2,4	1.0			1.2	1.2
Tribelos fuscicornis	1.6	1.1		2.4	2.6	1.7
Tribelos jucundus	1.8			1.3	3.1	1.4

Table 11 (continued)

Organism	Station					
	VC-2	HC-1	TC-1	TC-2	TC-3	Annual
Tanytarsus sp.	1.3	1.9	1.9	1.2	1.6	1.5
Stenochironomus sp.				1.3		0.4
Cryptochironomus digitatus	1.2	1.0			1.6	1.1
nr *Nilothauma* sp.	1.0					0.6
Micropsectra sp.				1.4		0.6
Cladotanytarsus sp.		1.3				0.3
Stictochironomus sp.	1.3	1.6		1.6	1.5	1.3
Paralauterborniella nigrohalteralis				1.0		0.4
Robakia sp.	1.1	1.7				0.6
Eukiefferiella sp.	1.3					0.5
Palpomyia tibialis	1.4	2.7	2.7	2.8	8.1	3.5
Palpomyia sp.			1.1	1.1		0.7
Macronemum sp.				1.0		0.2
Phylocentropus sp.	1.2	1.0		2.0	1.2	1.3
Amnicola sp.				1.3		0.7
Sphaerium sp.	2.1	2.0	1.3	3.3		2.0
Total Percent	89.6	91.0	84.0	87.0	89.6	94.4

was limited to less than 1.0% at all stations.

The mayfly Stenonema sp. was the only ephemeropteran collected at all stations. It ranged in abundance from less than 1.0% at Stations HC-1, TC-1, TC-2, and TC-3 to 2.2% at Station VC-2 (Table 11).

Beetles were abundant only at Station TC-3 although they were collected at all stations. The elmid beetle larva Stenelmis sp. was the only coleopteran collected at all stations with extremes of abundance ranging from less than 1.0% at Stations VC-2, HC-1, TC-1, and TC-2 to 1.5% at Station TC-3 (Table 11).

The gill-breathing snail Amnicola sp. was the only gastropod collected at all stations. Its greatest abundance was found at Station TC-2 where it comprised 1.3% of the total annual number of individuals (Table 11).

The fingernail clam Sphaerium sp. was the dominant bivalve and the only pelecypod collected at all stations. It ranged in abundance from less than 1.0% at Station TC-3 to 3.3% at Station TC-2 (Table 11).

Shannon's diversity index ($\bar{d}$) often yields values greater than three when applied to data obtained from clean water streams due to many different taxa represented by relatively few individuals. This tends to increase the complexity and stability of the community. Values below one occur when the index is applied to data from polluted streams due to many individuals distrubuted among only a few taxa. This tends to decrease the complexity and stability of the aquatic community. Benthic macroinvertebrate community structure is also affected by physical factors such as substrate type and the scouring effects of high discharge. Diversity ($\bar{d}$) values of all collections ranged from 1.31 at Station HC-1 during February to 4.38 at Station

VC-2 during October (Table 9). Diversity values were generally lowest during February when water temperatures were low and stream discharge was high.

The substrate at all stations consisted of coarse sand with sparse pockets of leaf litter and detritus. This type of substrate is unstable in that it "shifts" during periods of high flow making it difficult for benthic organisms to remain attached to the bottom. This was definitely the cause of the low $\bar{d}$ values during February and may have contributed to the low $\bar{d}$ value (1.84) obtained at Station TC-1 during April (Table 9).

The numbers of oligochaetes, especially the eurytolerant *Limnodrilus hoffmeisteri*, increased dramatically between the October and February collections at all stations, indicating that these organisms are able to tolerate the stress of high stream velocities and shifting substrate. The numbers of oligochaetes remained relatively high at Stations VC-2 and TC-3 during the April collections. Numbers of these organisms decreased significantly during the July collections, a period of severe drought, when only base flow existed in all the streams. It is interesting to note that Station HC-1, having the highest percentage of *Limnodrilus hoffmeisteri*, also had the lowest annual $\bar{d}$ (2.34), whereas, Station TC-1, having the lowest percentage of *Limnodrilus hoffmeisteri*, had the highest annual $\bar{d}$ (3.67). The relatively low annual $\bar{d}$ value (2.34) at Station HC-1 was probably due to the harsh environment of the coarse sand substrate since no excessive chemical stress was observed at this station.

During the April sampling period excessive chlorides were detected at all three Village Creek stations. The $\bar{d}$ value at Station

VC-2 during that sampling period was 1.96, a value significantly lower than the values from that station during the other three sampling periods. The $\bar{d}$ value of 1.96 during April is significant in that it represents at least 95 percent of the asymptotic diversity value (Table 9, Appendix D) which indicates that the macrobenthic community was in stress due presumably to the high chloride concentrations.

The low diversity value (2.87) obtained at Station TC-1 during July was directly related to unusually high numbers of the amphipod Gammarus sp. The clumped distribution in this taxa was evident since 140 of the 162 Gammarus sp. reported for Station TC-1 during July were obtained in a single grab.

The diversity values in the present study closely parallel the $\bar{d}$ values reported from Pine Island and Little Pine Island Bayous (Darville, 1978). The Pine Island Bayou watershed was affected by oil field brines and treated domestic wastewater, but the study was also hampered by extremely high discharge. Other investigators of Big Thicket streams have reported $\bar{d}$ values higher than those of the present study (Table 12).

Each station during each collection was analyzed to determine if an asymptotic diversity value was obtained. This was accomplished by progressively pooling data for each grab at each station and computing a $\bar{d}$ value beginning with the first two grabs collected. If an asymptotic diversity was obtained the station $\bar{d}$ value would fluctuate less than 5.0% from the previous pooled value (Wilhm, 1970).

An asymptotic diversity value was obtained in ten of the twenty $\bar{d}$ values reported for individual collections (Table 9, Appendix D). Many of the low $\bar{d}$ values did not represent asymptotic diversity,

Table 12

Collections and Annual Comparison of Numbers of Taxa and $\bar{d}$ Values in Big Thicket Streams

Stream and Investigator	Total Taxa (Annual)	$\bar{d}$
Village Creek (Tatum & Commander, 1971)	56	0.0 - 3.88
Village Creek (Lewis, 1974)	143	0 - 4.50 (2.21 - 4.93)*
Beech Creek (Kost, 1977)	172	3.22 - 4.62 (4.29 - 4.92)*
Little Pine Island and Pine Island Bayous (Darville, 1978)	123	1.16 - 3.87 (2.57 - 3.82)*
Menard Creek (Bass, 1979)	125	1.22 - 3.99 (3.36 - 4.37)*
Village, Hickory, and Turkey creeks (Present Study)	134	1.31 - 4.38 (2.34 - 3.67)*

*Annual $\bar{d}$ values

indicating that these values may have been higher if more grabs had been collected. The low $\overline{d}$ value of 1.96 computed for Station VC-2 during April represents at least 95 percent of the asymptotic diversity value which indicates that the macrobenthic community was in stress, due presumably to high chloride concentrations.

Sorenson's (1948) index of similarity was used to compare faunal similarity between stations. The highest value (0.70) was computed when comparing Stations TC-1 and TC-3 (Table 13), whereas the lowest value (0.55) was computed when comparing Stations TC-3 and HC-1 which represents a difference of only 27 percent. The faunal similarities reported for the present study are almost identical in magnitude to the annual values reported from Menard Creek (Bass, 1979).

Table 13

Annual Coefficients of Similarity
Between Stations

Station	VC-2	HC-1	TC-1	TC-2	TC-3
VC-2	----				
HC-1	0.56	----			
TC-1	0.64	0.61	----		
TC-2	0.59	0.56	0.65	----	
TC-3	0.60	0.55	0.70	0.59	----

SUMMARY AND CONCLUSIONS

Water quality of the streams of the Turkey Creek Unit of the Big Thicket National Preserve was studied from August, 1979 to July, 1980.

There are five permitted waste discharges in the watersheds upstream from the Turkey Creek Unit, all of which represent treated domestic wastewater. The total biochemical oxygen demand loading of 30.4 lbs/day for all discharges combined is projected to increase to 157 lbs/day by the year 2000.

Physicochemical conditions, in general, were excellent. High chloride concentrations due, presumably, to oil field brines were detected at all three Village Creek stations during the April sampling period. Temperature varied from 8.5 C to 28.5 C. Dissolved oxygen percent saturation was greater than 79 percent for all sampling periods, a level indicative of excellent water quality. Bicarbonate alkalinity, pH, and carbon dioxide were low at all stations, a normal condition for tannic acid laden streams. Turbidity, apparent color, total suspended solids, and total dissolved solids fluctuated with extremes of discharge.

Stream discharge ranged from 0.5 M^3/sec. at Station HC-1 during July to 33.3 M^3/sec. at Station VC-3 during March.

Bacterial contamination of streams in the Turkey Creek Unit was very slight with no evident trends other than increases during periods of excessive runoff.

A total of 6102 benthic macroinvertebrate organisms constituting

134 taxa were collected. The eurytolerant oligochaete, Limnodrilus hoffmeisteri was the dominant organism at all stations sampled for benthics. The annual occurrence of L. hoffmeisteri ranged from 34% at Station TC-1 to 70% at Station HC-1.

The number of taxa for all collections ranged from 11 at Station TC-1 during April to 44 at Station TC-2 during October. Numbers of individuals for all collections varied from 41 at Station HC-1 during July to 766 at Station HC-1 during February. Numbers of individuals generally increased with discharge.

Diversity ($\bar{d}$) values of all collections ranged from 1.31 at Station HC-1 during February to 4.38 at Station VC-2 during October. Diversity values were generally lowest during February when water temperatures were low and stream discharge was high. The coarse, shifting sand substrate also contributed to the low $\bar{d}$ values in February and may have been a factor in depressing the $\bar{d}$ value at Station TC-1 during April.

An asymptotic diversity value was obtained in ten of the twenty $\bar{d}$ values reported for individual collections.

Excessive chlorides due presumably to oil field brines caused stress within the macrobenthic community at Station VC-2 during April. The $\bar{d}$ value at that station during that sampling period was 1.96, a value significantly lower than the values from that station during the other three sampling periods.

Faunal similarity between stations ranged from 0.55 to 0.70 which indicates that all benthic stations had similar faunal structure on an annual basis. Coefficients of similarity indicated that Stations TC-1 and TC-3 had the most similar faunas.

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APPENDIX A

PHYSICOCHEMICAL METHODS

PHYSICOCHEMICAL METHODS

Water Temperature - Yellow Springs Instruments Model 57 oxygen-temperature meter.

Dissolved Oxygen - Yellow Springs Instruments Model 57 oxygen-temperature meter calibrated against the azide modification of the Winkler dissolved oxygen titration using saturated distilled water.

Oxygen Percent Saturation - calculated by use of temperature, dissolved oxygen concentrations and tables of oxygen saturation.

Biochemical Oxygen Demand - the difference in dissolved oxygen, expressed in mg/l, of samples of pure stream water before and after incubation at 20 C for five days.

Carbon Dioxide - titratration with 0.0227N sodium hydroxide to the phenolphthalein end point.

Total Alkalinity - titratration with 0.02N sulfuric acid to the brom cresol green-methyl red end point.

pH - Hellige pH colorimetric comparator.

Specific Conductance - Lab Line, Lectro Mho model conductivity bridge.

Chloride - the Mohr argentometric method involving titration with 0.014N silver nitrate to the potassium dichromate end point.

Turbidity - Bausch and Lomb Spectronic 20 spectrophotometer percent transmittance reading at 320 nm, applied to a

table constructed against standard formazin solutions using a Jackson candle turbidimeter.

Apparent Color - Hach Chemical Company direct reading colorimeter.

Orthophosphate (PO_4) - ascorbic acid method (Hach modification) percent transmittance read at 700 nm with a Bausch and Lomb Spectronic 20 spectrophotometer.

Ammonia Nitrogen (NH_4^+) - the Nessler method, percent transmittance read at 425 nm using a Bausch and Lomb Spectronic 20 spectrophotometer.

Nitrate Nitrogen (NO_3) - the cadmium reduction method (Hach modification), percent transmittance read at 500 nm using a Bausch and Lomb Spectronic 20 spectrophotometer.

Iron, Total (Fe^{++}) - 1, 10 phenanthroline method, percent transmittance read at 510 nm using a Bausch and Lomb Spectronic 20 spectrophotometer.

Total Suspended Solids - vacuum filtration through a 0.45 micron (pore size) filter using gravimetric methods.

Total Dissolved Solids - differential weight of filtrate before and after drying at 95 C and ignition at 550 C.

Chlorophyll "a" - the acetone extraction method reading optical density at 665 nm using a Bausch and Lomb Spectronic 20 spectrophotometer and substituting into the following formula:

$$o.d._{665}\ (13.4)\ \frac{\text{ml of acetone used}}{1000\ (\text{sample size in liters})} = \text{chlorophyll "a" (mg/l)}$$

APPENDIX B

PHYSICOCHEMICAL DATA

Physicochemical Conditions of Streams of the Turkey Creek Unit on August 21, 1979

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	25	25	24.5	24.1	25	24.9	24
Dissolved Oxygen, mg/l	7.4	7.4	7.6	8.1	7.9	7.8	7.9
O_2 Saturation, %	91	91	93	98	97	96	96
BOD_5, mg/l	1.8	1.6	2.3	1.7	1.5	1.6	1.5
CO_2, mg/l	7	6.5	6	5	4.5	5.5	2.5
Total Alkalinity, mg/l	13	13	13	12	13	11	13
p^H	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Spec. Cond., umhos/cm	58	63	66	73	54	54	55
Chloride, mg/l	12.5	14.5	15.5	19.5	11	11.5	11.5
Turbidity, JTU	92	86	81	73	68	71	71
Apparent Color, APHA units	188	163	160	130	100	120	123
PO_4, mg/l	0.06	0.06	0.08	0.05	0.2	0.16	0.16
NH_4, mg/l	1.18	1.03	1.03	0.76	0.65	0.67	0.65
NO_3, mg/l	0.003	0.006	0.007	0.01	0.015	0.016	0.014
Total Iron, mg/l	1.77	1.51	1.46	1.31	1.47	1.47	1.56
TSS, mg/l	19	14	62	5	8	18	13
TDS, mg/l	134	158	152	60	150	154	68
TDO, mg/l	110	74	130	48	98	110	48
TDI, mg/l	24	84	22	12	52	44	20
Chlorophyll "a", mg/l	0.0134	0.0	0.0	0.0	0.0	0.0	0.0

Physicochemical Conditions of Streams
of the Turkey Creek Unit
on September 17, 1979

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	21.5	21	21	20.5	20	20.5	20.5
Dissolved Oxygen, mg/l	8	8.2	8.3	8.7	8.7	8.9	8.7
O_2 Saturation, %	92.9	94.5	95.6	99.3	98.4	101.6	99.3
BOD_5, mg/l	1.4	1.3	1.5	1.3	1.5	1.7	1.4
CO_2, mg/l	5	3	4.5	4	4.5	4	4
Total Alkalinity, mg/l	14	14	14	13	13	14	14
p^H	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Spec. Cond., umhos/cm	63	69	71	76	57	58	57
Chloride, mg/l	14	16	15	20	17	12	12
Turbidity, JTU	61	61	59	59	54	56	56
Apparent Color, APHA units	120	110	112	106	81	91	100
PO_4, mg/l	0.09	0.08	0.08	0.07	0.18	0.17	0.12
NH_4, mg/l	0.65	0.56	0.56	0.54	0.46	0.5	0.48
NO_3, mg/l	0.007	0.008	0.009	0.009	0.016	0.016	0.014
Total Iron, mg/l	1.39	1.24	1.24	1.08	1.05	1.08	1.11
TSS, mg/l	6	8	29	14	19	10	17
TOS, mg/l	6	9	74	46	15	14	64
TDO, mg/l	4	7	62	34	11	12	58
TOI, mg/l	2	2	12	12	4	2	6
Chlorophyll "a", mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0134

Physicochemical Conditions of Streams
of the Turkey Creek Unit
on October 19, 1979

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	21.5	20.5	20.5	20.5	21.5	21.5	20.5
Dissolved Oxygen, mg/l	8.1	8.3	8.5	8.6	8.3	8.5	8.5
O_2 Saturation %	93.6	94.7	97	98.2	96.4	98.7	97
BOD_5, mg/l	1.5	1.3	1.6	1.3	1.2	1.5	1.3
CO_2, mg/l	12	5	5	12	5	5	5
Total Alkalinity, mg/l	14	12	13	12	14	14	13
p^H	6.3	6.3	6.3	6.1	6.5	6.5	6.3
Spec. Cond., umhos/cm	58	61	61	67	56	56	57
Chloride, mg/l	14.5	15	14.5	18	12	12	11.5
Turbidity, JTU	51	51	56	61	54	64	75
Apparent Color APHA units	120	110	100	80	82	80	90
PO_4, mg/l	0.09	0.05	0.06	0.08	0.11	0.08	0.09
NH_4, mg/l	0.58	0.5	0.54	0.52	0.44	0.46	0.46
NO_3, mg/l	0.002	0.003	0.004	0.004	0.014	0.014	0.013
Total Iron, mg/l	1.05	0.99	0.99	0.89	1.02	1.02	0.99
TSS, mg/l	36	6	35	12	12	45	17
TOS, mg/l	74	68	60	64	52	54	40
TOO, mg/l	30	28	32	14	32	42	32
TOI, mg/l	44	40	28	50	20	12	8
Chlorophyll "a", mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Physicochemical Conditions of Streams of the Turkey Creek Unit on November 30, 1979

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1*	TC-1	TC-2	TC-3 *
Temp., ^{o}C	9	8.5	10	9	9	9	10
Dissolved Oxygen, mg/l	10.2	9.1	9.7	9.8	10.8	11.2	10.6
O_2 Saturation, %	91	80	89	97	97	100	97
BOD_5, mg/l	2.3	1.7	2.3	3.2	2.4	3.1	2.6
CO_2, mg/l	5	8	4.5	4.5	4	5	6
Total Alkalinity, mg/l	9	9	9	9	12	12	12
p^H	5.9	5.8	5.9	6	6.2	6.1	6.1
Spec. Cond., umhos/cm	54	51	51	44	48	47	48
Chloride, mg/l	13	13	14	12	12	11.5	11.5
Turbidity, JTU	80	81	81	73	64	68	71
Apparent Color, APHA units	160	170	162	140	112	125	125
PO_4, mg/l	0.07	0.05	0.06	0.06	0.08	0.08	0.07
NH_4, mg/l	1.40	1.29	1.29	0.94	0.74	0.86	0.86
NO_3, mg/l	0.001	0.001	0.001	0.002	0.003	0.003	0.003
Total Iron, mg/l	0.92	0.89	0.84	0.84	0.97	1.02	1.05
TSS, mg/l	16	18	25	13	9	13	20
TOS, mg/l	86	88	60	58	52	70	74
TOO, mg/l	34	44	54	40	38	69	54
TOI, mg/l	52	44	6	18	14	1	20
Chlorophyll "a", mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0

*Sampled at county road northeast of Village Mills due to flooding conditions

Physicochemical Conditions of Streams
of the Turkey Creek Unit
on December 20, 1979

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	10	10	9.5	9	11	10	9.5
Dissolved Oxygen, mg/l	10.4	10.9	10.6	11	11	11.1	11
O_2 Saturation, %	95	100	96	98	103	102	99
BOD_5, mg/l	2.2	2.1	2	2	1.6	1.8	2.1
CO_2, mg/l	4	5	4.5	4	2	3	3
Total Alkalinity, mg/l	10	10	10	9	10	10	9
p^H	6	6	6	5.9	6.1	6.1	6.1
Spec. Cond., umhos/cm	61	53	52	48	42	41	42
Chloride, mg/l	15	15	15	15	11	11	11
Turbidity, JTU	61	59	61	68	51	59	65
Apparent Color, APHA units	140	115	120	130	80	90	115
PO_4, mg/l	0.07	0.07	0.07	0.05	0.06	0.07	0.07
NH_4, mg/l	1.25	1.09	1.15	0.97	0.65	0.72	0.81
NO_3, mg/l	0.004	0.002	0.003	0.003	0.003	0.004	0.003
Total Iron, mg/l	0.94	0.89	0.94	0.87	0.89	0.92	0.99
TSS, mg/l	19	7	21	17	14	7	22
TDS, mg/l	56	60	50	54	40	50	80
TDO, mg/l	36	14	16	18	22	6	26
TDI, mg/l	20	46	34	36	18	44	54
Chlorophyll "a", mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Physicochemical Conditions of Streams
of the Turkey Creek Unit
on January 29, 1980

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1*	TC-1	TC-2	TC-3*
Temp., ^{o}C	11.5	11.5	11.5	11.3	11.1	11.3	11.3
Dissolved Oxygen, mg/l	9.6	9.8	9.8	10.2	10.3	10	10
O_2 Saturation, %	91	93	93	96	97	94	94
BOD_5, mg/l	2.1	2.1	1.9	1.6	1.6	1.3	1.4
CO_2, mg/l	5	5	5	5	4	4	5
Total Alkalinity, mg/l	9	9	9	9	11	11	9
p^H	5.1	5.1	5.3	5.1	5.3	5.3	5.2
Spec. Cond., umhos/cm	58	60	57	50	52	51	51
Chloride, mg/l	13.5	14	13.5	11.5	11	11.5	11
Turbidity, JTU	84	90	84	75	71	77	80
Apparent Color, APHA units	218	218	208	170	145	165	170
PO_4, mg/l	0.01	0.03	0.02	0.09	0.05	0.07	0.06
NH_4, mg/l	1.43	1.32	1.29	0.97	0.79	0.89	0.92
NO_3, mg/l	0.002	0.003	0.002	0.004	0.007	0.006	0.007
Total Iron, mg/l	1.11	1.14	1.11	1.11	1.17	1.2	1.24
TSS, mg/l	21	23	27	30	11	21	28
TOS, mg/l	108	88	86	66	76	82	82
TOO, mg/l	12	20	26	14	12	0	14
TOI, mg/l	96	68	60	52	54	82	68
Chlorophyl "a", mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0

*Sampled at county road northeast of Village Mills due to flooding conditions

Physicochemical Conditions of Streams
of the Turkey Creek Unit
on February 26, 1980

Parameter	Station						
	VC-2	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	14	14	14	13.5	13.5	14	14
Dissolved Oxygen, mg/l	8.8	9.6	9.2	9.5	9.4	9.1	9.2
O_2 Saturation, %	88	96	92	94	93	91	92
BOD_5, mg/l	1.2	1.8	1.4	1.2	0.6	0.5	0.4
CO_2, mg/l	6.5	4	4	4	4	3.5	4
Total Alkalinity, mg/l	13	12	12	10	14	13	12
p^H	6.1	6.1	6.2	6.1	6.3	6.2	6.2
Spec. Cond., umhos/cm	61	66	65	52	57	51	54
Chloride, mg/l	15	15	15	15	12	12	12
Turbidity, JTU	86	95	99	88	84	81	97
Apparent Color, APHA units	160	175	190	162	142	135	160
PO_4, mg/l	0.01	0.01	0.01	0.01	0.06	0.07	0.12
NH_4, mg/l	0.92	0.86	0.94	0.86	0.65	0.72	0.76
NO_3, mg/l	0.003	0.003	0.002	0.004	0.009	0.01	0.01
Total Iron, mg/l	1.11	1.11	1.14	1.11	1.11	1.14	1.14
TSS, mg/l	21	25	43	33	17	13	22
TDS, mg/l	58	74	60	60	70	72	52
TDO, mg/l	20	18	22	16	18	24	8
TDI, mg/l	38	56	38	44	52	48	44
Chlorophyll "a", mg/l	0.0	0.0	0.0	0.0	0 0	0.0	0.0

Physicochemical Conditions of Streams of the Turkey Creek Unit on March 25, 1980

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	16	16	15.5	15.5	15.5	16	15.5
Dissolved Oxygen, mg/l	8.2	8.7	8.8	9	8.9	9.4	9.3
O_2 Saturation, %	86	91	84	93	92	98	96
BOD_5, mg/l	1.9	2	2.3	1.7	1.6	2	1.8
CO_2, mg/l	7	5	5	4.5	4	4	3
Total Alkalinity, mg/l	13	11	11	11	1[illegible]	12	11
p^H	6.1	6	6.1	6.1	6.3	6.1	6.1
Spec. Cond., umhos/cm	83	73	72	60	63	58	56
Chloride, mg/l	18	16.5	16	14	12.5	12.5	12.5
Turbidity, JTU	109	109	109	114	105	109	92
Apparent Color, APHA units	270	275	270	285	250	250	218
PO_4, mg/l	0.12	0.09	0.09	0.16	0.17	0.2	0.16
NH_4, mg/l	1.79	1.74	1.84	1.84	1.29	1.25	1.22
NO_3, mg/l	0.001	0.001	0.001	0.002	0.006	0.009	0.007
Total Iron, mg/l	1.35	1.46	1.51	1.61	1.72	1.77	1.56
TSS, mg/l	62	47	49	55	68	54	43
TDS, mg/l	106	94	98	102	74	58	74
TDO, mg/l	54	50	66	46	30	18	12
TDI, mg/l	52	44	32	56	44	40	62
Chlorophyll "a", mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Physicochemical Conditions of Streams
of the Turkey Creek Unit
on April 22, 1980

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	18	17.5	18	16.2	18.2	18	17.5
Dissolved Oxygen, mg/l	7.5	7.8	8	8.2	9.1	8.2	8.2
O_2 Saturation, %	82	84	87	86	99	89	88
BOD_5, mg/l	0.9	0.6	0.6	0.5	1.5	0.6	0.6
CO_2, mg/l	6.5	6.5	5	4	5	5	4
Total Alkalinity, mg/l	15	13	15	11	15	13	13
p^H	6.1	6	6.1	6	6.1	6.2	6.1
Spec. Cond., umhos/cm	410	290	206	83	63	62	61
Chloride, mg/l	136	88	60	13	11.5	11	11.5
Turbidity, JTU	75	75	71	73	64	59	68
Apparent Color, APHA units	160	160	145	155	130	128	142
PO_4, mg/l	0.08	0.07	0.08	0.07	0.14	0.12	0.13
NH_4, mg/l	1.25	1.09	1.06	0.86	0.67	0.72	0.72
NO_3, mg/l	0.003	0.003	0.004	0.004	0.01	0.013	0.014
Total Iron, mg/l	1.14	1.14	1.14	1.14	1.24	1.17	1.2
TSS, mg/l	26	24	26	31	22	26	28
TDS, mg/l	226	170	130	58	52	48	58
TDO, mg/l	26	38	28	24	22	16	4
TDI, mg/l	200	132	102	34	30	32	56
Chlorophyll "a", mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Physicochemical Conditions of Streams
of the Turkey Creek Unit
on May 27, 1980

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	24.5	24	23.7	23	26.3	24	23.2
Dissolved Oxygen, mg/l	6.5	6.7	6.9	7.4	7.7	7.5	7
O_2 Saturation, %	79	81	83	88	97	91	84
BOD_5, mg/l	1.6	1.7	1.5	1.3	1.7	1.5	1.1
CO_2, mg/l	10	9	8	8	8	8	8
Total Alkalinity, mg/l	15	12	14	12	15	15	14
p^H	6.1	6.1	6.1	6.1	6.3	6.3	6.2
Spec. Cond., umhos/cm	73	63	61	60	58	58	57
Chloride, mg/l	13	12	12	12.5	9.5	9.5	10
Turbidity, JTU	95	92	88	95	86	86	92
Apparent Color, APHA units	220	210	200	200	172	180	192
PO_4, mg/l	0.08	0.08	0.08	0.07	0.13	0.09	0.12
NH_4, mg/l	1.43	1.29	1.18	1.12	0.89	0.89	0.92
NO_3, mg/l	0.001	0.002	0.003	0.003	0.009	0.011	0.01
Total Iron, mg/l	1.51	1.47	1.47	1.47	1.51	1.47	1.35
TSS, mg/l	35	33	34	38	33	39	36
TDS, mg/l	70	72	74	72	64	60	72
TDO, mg/l	28	28	48	38	28	16	40
TDI, mg/l	42	44	26	34	36	44	32
Chlorophyll "a", mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Physicochemical Conditions of Streams of the Turkey Creek Unit on June 18, 1980

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	26	25.2	25.1	24.3	25.8	25.5	24.7
Dissolved Oxygen, mg/l	6.7	6.6	6.7	7.1	7.4	7	6.8
O_2 Saturation, %	84	82	83	86	92	87	83
BOD_5, mg/l	1.1	0.4	0.4	0.6	0.7	0.4	0.2
CO_2, mg/l	7.5	7	6	6.5	5.5	5	5.5
Total Alkalinity, mg/l	17	15	15	12	16	16	17
p^H	6.2	6.2	6.3	6.1	6.4	6.3	6.2
Spec. Cond., umhos/cm	78	72	67	69	58	59	58
Chloride, mg/l	15.5	15.5	13.5	15.5	11	11	10.5
Turbidity, JTU	64	65	64	65	61	61	68
Apparent Color, APHA units	148	148	130	130	130	130	128
PO_4, mg/l	0.08	0.08	0.11	0.08	0.18	0.18	0.16
NH_4, mg/l	0.6	0.56	0.56	0.52	0.4[illegible]	0.48	0.44
NO_3, mg/l	0.008	0.011	0.014	0.012	0.019	0.02	0.021
Total Iron, mg/l	1.46	1.31	1.31	1.2	1.39	1.39	1.31
TSS, mg/l	21	16	18	22	17	18	13
TDS, mg/l	68	74	46	60	74	58	60
TOO, mg/l	6	60	2	28	32	42	12
TDI, mg/l	62	14	44	32	42	16	48
Chlorophyll "a", mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Physicochemical Conditions of Streams
of the Turkey Creek Unit
on July 15, 1980

Parameter	Station						
	VC-1	VC-2	VC-3	HC-1	TC-1	TC-2	TC-3
Temp., ^{o}C	28	28	28	27.5	28.5	28.5	27.8
Dissolved Oxygen, mg/l	6.2	6.7	6.8	7.1	7.6	7.2	7.4
O_2 Saturation, %	80	86	88	91	99	94	95
BOD_5, mg/l	0.8	1.1	1	0.9	1.2	1.4	1.2
CO_2, mg/l	7.5	9.5	9	7	9.5	8	9
Total Alkalinity, mg/l	20	18	24	14	20	24	20
p^H	6.6	6.6	6.4	6.3	6.3	6.4	6.4
Spec. Cond., umhos/cm	70	66	64	66	60	61	62
Chloride, mg/l	17.5	14.5	14	17	12	11	12
Turbidity, JTU	56	54	51	51	47	56	47
Apparent Color, APHA units	115	110	105	100	85	100	90
PO_4, mg/l	0.11	0.08	0.08	0.11	0.22	0.22	0.16
NH_4, mg/l	0.6	0.58	0.58	0.54	0.44	0.5	0.46
NO_3, mg/l	0.002	0.003	0.007	0.005	0.023	0.022	0.014
Total Iron, mg/l	1.51	1.27	1.24	1.05	0.14	1.14	1.11
TSS, mg/l	7	5	8	6	9	9	8
TDS, mg/l	76	88	60	68	66	60	56
TDO, mg/l	44	38	30	28	32	44	26
TDI, mg/l	32	50	30	40	34	16	30
Chlorophyll "a", mg/l	0.034	0.027	0.027	0.027	0.02	0.013	0.027

APPENDIX C

BENTHIC MACROINVERTEBRATE DATA

Numbers of Benthic Macroinvertebrates Collected From
Turkey Creek Unit Streams
on October 17, 1980

Taxa	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Platyhelminthes					
Turbellaria					
Tricladida					
Dugesia sp.			1		
Nematoda	1		2		
Annelida					
Oligochaeta					
Naididae					
Nais sp.					1
Tubificidae					
Branchiura sowerbyi			83	1	
Limnodrilus hoffmeisteri	15	12	139	189	101
Peloscolex sp.		15	83	35	36
Tubifex sp.	1				
Enchytraeidae					
Enchytraeus sp.	3		2	20	3
Lumbriculidae					
Lumbriculus variegatus	1	1			10
Hirudinea					
Glossiphoniidae					
Glossiphonia complanata			1		
Helobdella fusca			1		
Rhynchobdellidae					
Actinobdella annectens			1		
Arthropoda					
Crustacea					
Isopoda					
Asellus sp.	1				
Amphipoda					
Gammarus sp.	4		6	1	
Hyalella azteca	1				
Crangonyx sp.			7		
Synurella sp.			2		
Decapoda					
Orconectes sp.		1			
Palaemonetes kadiakensis				2	
Immature Decapoda	2				
Insecta					
Odonata					
Gomphus pallidus		2			
Gomphus sp.				1	

October 17, 1980 (continued)

Taxa	Station VC-2	HC-1	TC-1	TC-2	TC-3
Gomphoides sp.		2			
Dromogomphus spinosus			1		
Dromogomphus spoliatus					1
Dromogomphus sp.				1	
Erpetogomphus sp.				2	
Unknown Gomphidae		1			
8 *Cordulegaster* sp.		1			
Ephemeroptera					
Stenonema smithae	3				
Hexagenia rigida		13	3		
10 *Hexagenia limbata*			3		2
Hexagenia recurvata				1	
7 *Caenis* sp.				1	
Callibaetis sp.				2	1
Neocloeon sp.				1	
Pseudocloeon sp.				1	
10 *Siphlonurus* sp.				1	
Coleoptera					
Stenelmis sp.	4	1			8
Ancyronyx variegata				1	
Diptera					
5 Simuliidae					
Simulium sp.				2	
Tanypodinae					
Ablabesmyia hauberi			11	1	
Ablabesmyia mallochi				1	
Ablabesmyia sp.	4				
Nilotanypus sp.	1				
Clinotanypus sp.			1		
2 Chironominae					
Polypedilum halterale	1	1		3	8
Polypedilum illinoense	1		2	2	
Polypedilum convictum	1	1	1	14	2
Polypedilum ophioides					1
Tribelos fuscicornis			4	1	
Tribelos sp.	4			1	
Tanytarsus sp.	2	10	15	9	10
Stenochironomus sp.	3			2	
Chironomus sp.	3				
Cryptochironomus digitatus	1	1	4	4	8
Cryptochironomus fulvus					1
nr *Nilothauma* sp.	6			2	1
Zavrelia sp.		1			

October 17, 1980 (continued)

Taxa	Station VC-2	HC-1	TC-1	TC-2	TC-3
Micropsectra sp.	1	1	8	17	7
Demicryptochironomus sp.			3		
Paratanytarsus sp.			2		
Cladotanytarsus sp.			2		
Stempellina sp.			1		
Rheotanytarsus sp.				6	
Glyptotendipes sp.				2	
Microtendipes sp.					1
Nimbocera sp.					1
Unknown Tanytarsini	4				
5 Orthocladiinae					
Smittia sp.				2	
Psectrocladius sp.	1		1		
5 Ceratopogonidae					
Palpomyia tibialis	2	5	5	16	13
Palpomyia sp.	10		11	13	2
Culicoides sp.		1	1	1	
Stilobezzia sp.				1	
Trichoptera					
5 Hydropsychidae					
Macronemum sp.				13	
8 Psychomyiidae					
Polycentropus centralis	3				
Polycentropus sp.				1	
Phylocentropus sp.		1	1	5	
8 Philoptamidae					
Chimarra sp.				1	
10 Leptoceridae					
Oecetis sp.	1	5	1	3	4
Mollusca					
Gastropoda					
3 *Amnicola* sp.	1		7	4	2
Campeloma sp.			4	1	
Pelecypoda					
3 *Sphaerium* sp.	7	1	8	19	1
Lampsilis sp.			4	1	

October 17, 1980 (continued)

Taxa	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Total Number Individuals	92	73	431	405	224
Total Number Taxa	30	18	36	44	24
Diversity ($\overline{d}$)	4.38	3.54	3.29	3.34	2.98

Numbers of Benthic Macroinvertebrates Collected From
Turkey Creek Unit Streams
on February 26, 1980

Taxa	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Platyhelminthes					
Turbellaria					
Tricladida					
Dugesia sp.		1	2		
Nematoda	1		3	5	10
Nematomorpha			1		
Annelida					
Oligochaeta					
Opistocystidae					
Opistocysta tribranchiata		1			
Tubificidae					
Branchiura sowerbyi			118	21	1
Limnodrilus hoffmeisteri	392	651	109	273	277
Aulodrilus pigueti			2		10
Peloscolex sp.	76	14	3	17	4
Tubifex sp.			1		8
Enchytraeidae					
Enchytraeus sp.	4	3		1	
Lumbriculidae					
Lumbriculus variegatus					21
Rhynchelmis sp.					2
Hirudinea					
Rhynchobdellidae					
Actinobdella annectens			1		1
Arthropoda					
Crustacea					
Isopoda					
Asellus intermedius					1
Asellus militaris					1
Asellus sp.	1				
Amphipoda					
Gammarus sp.	2			15	3
Hyalella azteca	1			1	
Crangonyx sp.	1		2	3	
Synurella sp.	2				
Insecta					
Odonata					
Hagenius brevistylus	1			1	
Gomphus sp.	1			2	1
Dromogomphus sp.	1			1	1
Neoneura sp.				1	

February 26, 1980 (continued)

Taxa	Station VC-2	HC-1	TC-1	TC-2	TC-3
Ephemeroptera					
Stenonema femoratum	1				
Stenonema sp.	28	1	4	2	
Hexagenia limbata		6	2		
Coleoptera					
Stenelmis sp.	2			7	1
Diptera					
Tipulidae					
Hexatoma sp.		1	1	3	1
Tanypodinae					
Ablabesmyia hauberi	5				
Ablabesmyia mallochi					1
Ablabesmyia ornata	2				2
Ablabesmyia aspera	2	2		3	
Ablabesmyia annulata		4			
Ablabesmyia cinctipes				1	
Ablabesmyia tarella					3
Larsia sp.			1		
Chironominae					
Polypedilum halterale	20	8	7	2	24
Polypedilum illinoense	1	3	5	5	30
Polypedilum convictum	2	1		3	14
Polypedilum ophioides		1	2	1	13
Polypedilum fallax	1				1
Tribelos fuscicornis	16				
Tribelos jucundus	20	6		3	9
Tribelos sp.	1				1
Tanytarsus sp.	8	5	1	1	11
Stenochironomus sp.				14	1
Chironomus attenuatus	1				
Cryptochironomus digitatus	4	10	1	1	5
Cryptochironomus fulvus	2		1		3
Cryptochironomus blarina	1		1		1
nr *Nilothauma* sp.	5	2		9	2
Micropsectra sp.		1		1	1
Demicryptochironomus sp.		1			
Cladotanytarsus sp.		10			
Rheotanytarsus sp.			2		
Paralauterborniella nigrohalteralis		3	1	9	6
Leptochironomus sp.					1
Podionomus beckae					1
Unknown Chironomini					1

February 26, 1980 (continued)

Taxa	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Orthocladiinae					
Eukiefferiella sp.				4	
Corynoneura sp.	2				
Rheocricotopus sp.	1				
Brillia sp.	1				
Psectrocladius vernalis					1
Psectrocladius sp.				1	
Unknown Orthocladinae				4	
Ceratopogonidae					
Palpomyia tibialis	1	10	12	3	22
Palpomyia sp.	1	3		1	
Stilobezzia sp.			5		
Tricophtera					
Psychomyiidae					
Polycentropus sp.				1	
Phylocentropus sp.					1
Philoptamidae					
Chimarra sp.	2	4		1	
Leptoceridae					
Leptocerus sp.				1	
Mollusca					
Gastropoda					
Amnicola sp.	4	3	1	10	4
Campeloma sp.				2	
Pelecypoda					
Sphaerium sp.	20	4	2	10	3
Unknown Pelocypoda			1		
Total Number Individuals	644	766	180	438	518
Total Number Taxa	40	26	28	39	42
Diversity ($\bar{d}$)	2.47	1.31	2.65	2.68	3.08

Numbers of Benthic Macroinvertebrates Collected
From Turkey Creek Unit Streams
on April 22, 1980

Taxa	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Platyhelminthes					
Turbellaria					
Tricladida					
Dugesia sp.	1				
Nematoda	1			1	2
Annelida					
Oligochaeta					
Tubificidae					
Branchiura sowerbyi			10	1	
Limnodrilus hoffmeisteri	361	97	63	96	213
Aulodrilus pigueti	4				
Peloscolex sp.	57	3		2	7
Tubifex sp.	7	2	2	6	47
Lumbriculidae					
Lumbriculus variegatus	18	1	11	7	13
Hirudinea					
Erpobdellidae					
Erpobdella sp.			1		3
Arthropoda					
Crustacea					
Isopoda					
Asellus militaris				1	
Amphipoda					
Gammarus sp.				13	2
Crangonyx sp.				1	
Synurella sp.		1			
Insecta					
Odonata					
Gomphus sp.			1		2
Dromogomphus sp.	1			1	2
Plecoptera					
Perlesta sp.		1			
Ephemeroptera					
Stenonema sp.		2			
Hexagenia limbata	15				5
Coleoptera					
Stenelmis sp.				1	9
Dubiraphia sp.		1			
Tanypodinae					
Ablabesmyia mallochi				4	1
Ablabesmyia ornata	1	1			

April 22, 1980 (continued)

Taxa	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Ablabesmyia annulata					1
Tanypus sp.	1				
Procladius sp.		4			
Clinotanypus sp.					1
Chironominae					
Polypedilum halterale	2	5		2	4
Polypedilum ophioides	1				3
Tribelos fuscicornis	7	12		30	33
Tribelos jucundus	6	4		12	31
Tribelos sp.	1				
Tanytarsus sp.	2	6		1	
Cryptochironomus digitatus	11			1	7
Cryptochironomus fulvus	2	1			
Cryptochironomus blarina				1	1
Demicryptochironomus sp.					2
Cladotanytarsus sp.		3		1	
Rheotanytarsus sp.		2	1	4	1
Stictochironomus sp.		4			2
Paralauterborniella nigrohalteralis		1		4	
Paralauterborniella elachista		1			
Robackia sp.	3	13		2	1
Paratendipes connectens				1	
Orthocladiinae					
Psectrocladius vernalis		1			
Ceratopogonidae					
Palpomyia tibialis	3	9		6	58
Stilobezzia sp.		2			
Trichoptera					
Psychomyiidae					
Phylocentropus sp.	15	10	5	4	12
Hydroptilidae					
Agraylea sp.		1			
Leptoceridae					
Oecetis sp.		5	1	2	1
Mollusca					
Gastropoda					
Amnicola sp.	3	1	1	2	1
Campeloma sp.				1	
Pelecypoda					
Sphaerium sp.	2	17		11	7

April 22, 1980 (continued)

Taxa	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Glebula rotundata				1	
Unknown Pelecypoda			1		
Total Number Individuals	525	211	97	220	472
Total Number Taxa	24	29	11	30	29
Diversity ($\overline{d}$)	1.96	3.25	1.84	3.23	2.98

Numbers of Benthic Macroinvertebrates Collected From
Turkey Creek Unit Streams
on July 15, 1980

Taxa	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Platyhelminthes					
Turbellaria					
Tricladida					
Dugesia sp.			1		
Nematoda	1	1		2	2
Annelida					
Oligochaeta					
Tubificidae					
Branchiura sowerbyi			19	23	
Limnodrilus hoffmeisteri	28	5	38	84	27
Tubifex sp.					1
Lumbriculidae					
Lumbriculus variegatus			22		2
Hirudinea					
Erpobdellidae					
Erpobdella sp.	2		1		1
Arthropoda					
Crustacea					
Amphipoda					
Gammarus sp.	2		162	2	6
Hyalella azteca		1			
Decapoda					
Cambarellus puer			1		1
Insecta					
Odonata					
Gomphus sp.			1	4	1
Dromogomphus sp.			1		
Ephemeroptera					
Stenonema sp.	3	2	2	4	4
Caenis sp.	7		2		
Coleoptera					
Stenelmis sp.		1	1		1
Diptera					
Tipulidae					
Hexatoma sp.		1	1	1	1
Tanypodinae					
Ablabesmyia mallochi			1		
Ablabesmyia annulata			1		
Ablabesmyia tarella			1		
Thienemannimyia - group	2		2		
Chironominae					

July 15, 1980 (continued)

Taxa	Station VC-2	HC-1	TC-1	TC-2	TC-3
Polypedilum halterale	17	4	3	35	9
Polypedilum ophioides	34	10	4	6	1
Tribelos fuscicornis			3		
Tribelos jucundus			4	1	
Tanytarsus sp.	6		3	4	
Stenochironomus sp.	2		2		1
Chironomus sp.			1		
Cryptochironomus digitatus	1		2	3	1
Cryptochironomus fulvus				2	
Cryptochironomus blarina	4		1		
Nilothauma sp.	1				1
nr *Nilothauma* sp.	4		1		2
Cladotanytarsus sp.		1			
Stictochironomus sp.	11	1	7	5	3
Paralauterborniella nigrohalteralis					1
Robakia sp.	13	5			1
Dicrotendipes modestus	2				
Orthocladiinae					
Eukieferiella sp.	18		5	5	
Ceratopogonidae					
Palpomyia tibialis	14	5	11	10	11
Trichoptera					
Pyschomyiidae					
Phylocentropus sp.	2		2	17	2
Philoptamidae					
Chimarra sp.		4			
Leptoceridae					
Oecetis sp.	1			1	
Megaloptera					
Sialidae					
Sialis sp.				1	
Mollusca					
Gastropoda					
Amnicola sp.	2				
Campeloma sp.			1	1	
Pelecypoda					
Sphaerium sp.	1		3	2	1
Lampsilis sp.			1		
Unknown Pelecypoda					1

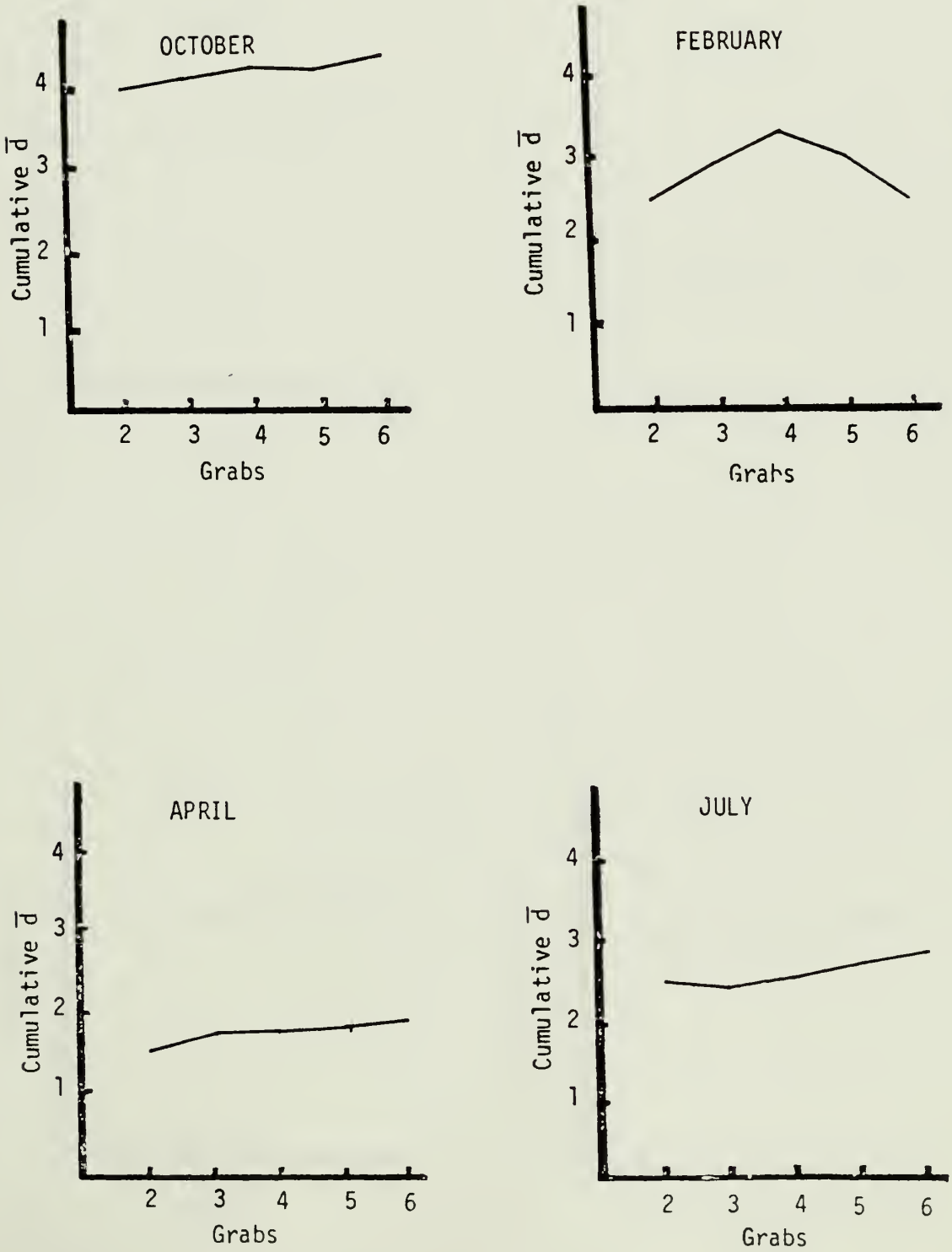
July 15, 1980 (continued)

Taxa	Station				
	VC-2	HC-1	TC-1	TC-2	TC-3
Total Number Individuals	178	41	311	213	82
Total Number Taxa	24	13	34	21	24
Diversity ($\overline{d}$)	3.76	3.26	2.87	3.05	3.54

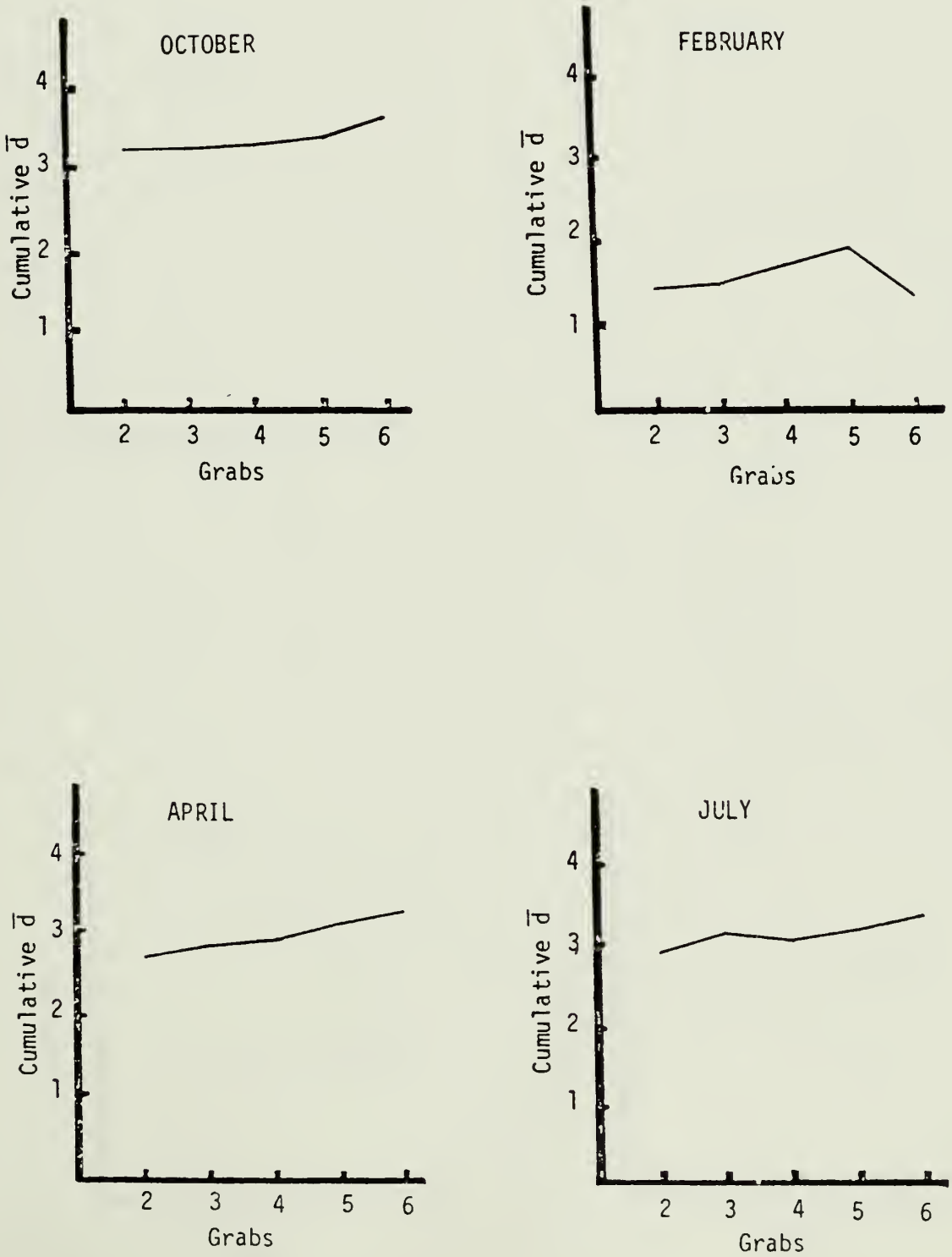
APPENDIX D

GRAPHS OF PROGRESSIVELY POOLED PONAR GRABS

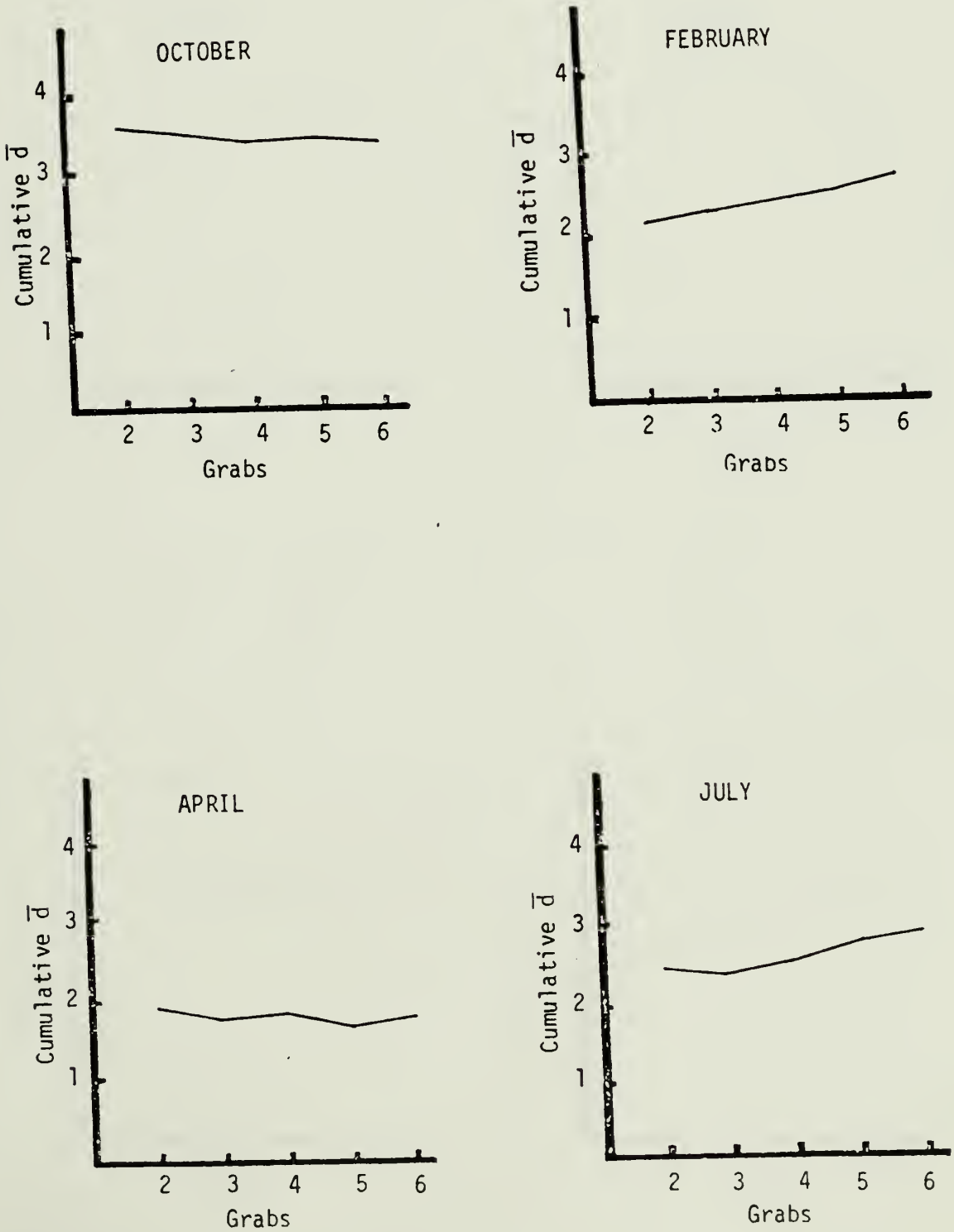
Diversity Values for Progressively Pooled
Ponar Grabs at Station VC-2



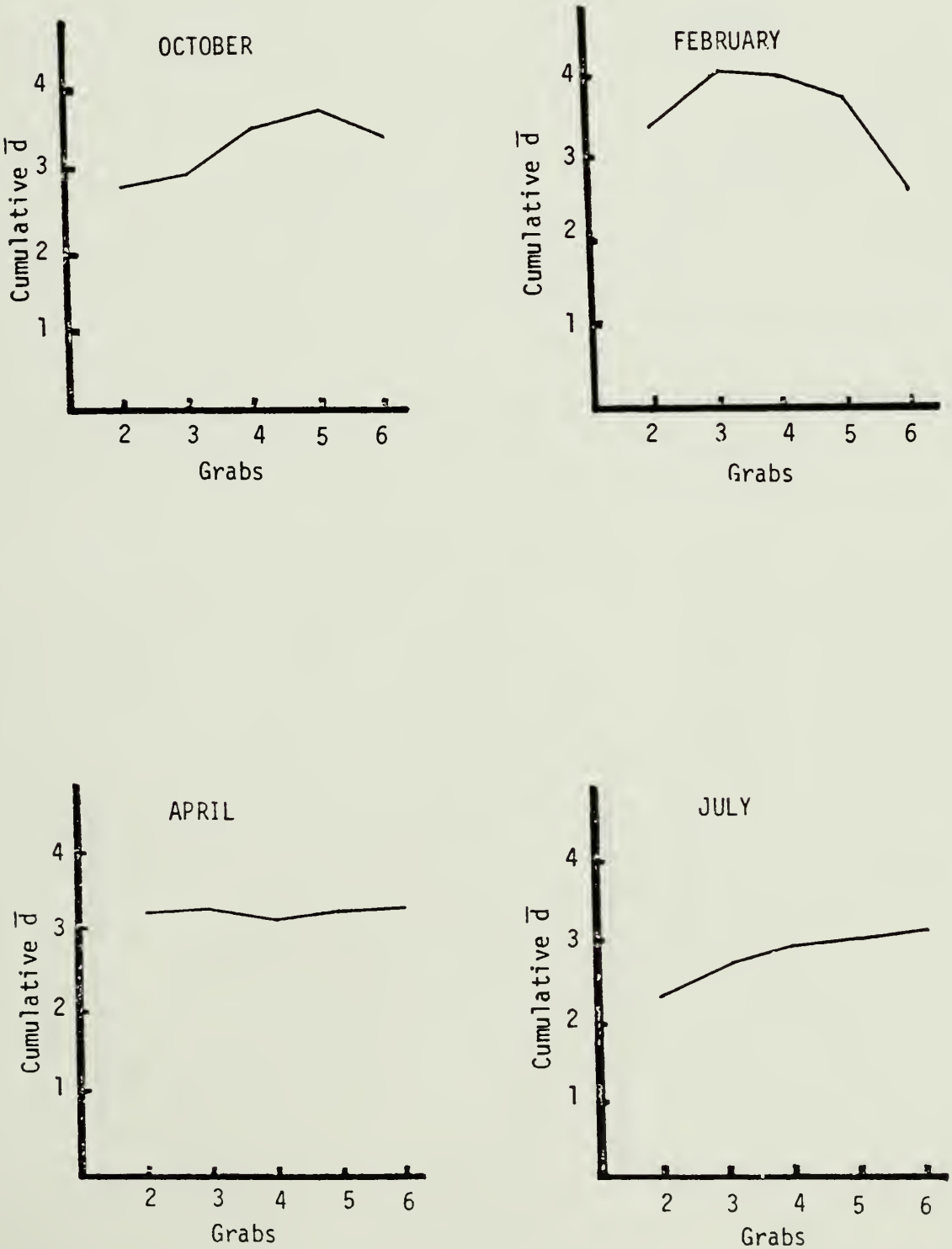
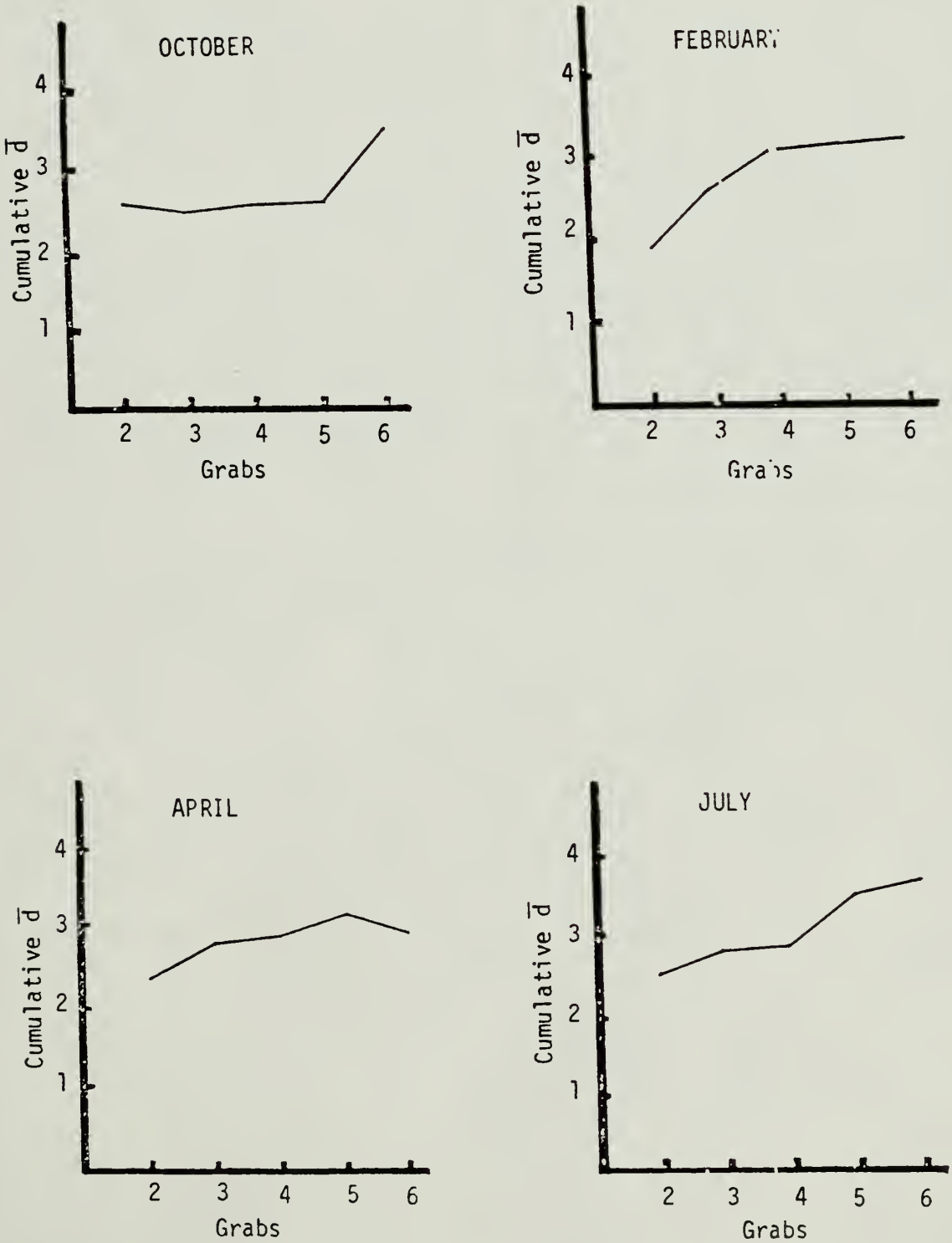
Diversity Values for Progressively Pooled
Ponar Grabs at Station HC-1



Diversity Values for Progressively Pooled
Ponar Grabs at Station TC-1



Diversity Values for Progressively Pooled
Ponar Grabs at Station TC-2



Diversity Values for Progressively Pooled
Ponar Grabs at Station TC-3